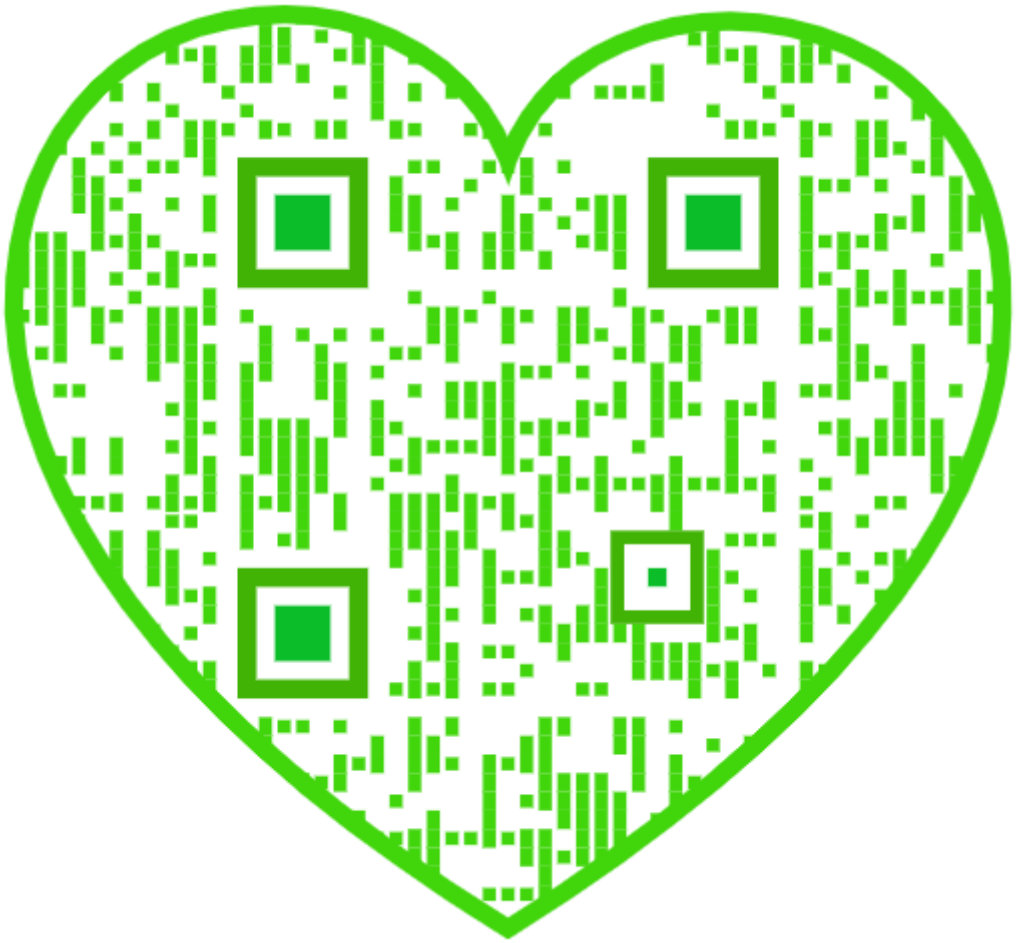

DESIGNS FOR SMALL DYNAMOS AND MOTORS

BY
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PREFACE

MOST of the chapters of this book originally formed articles written for the *American Electrician*, and many of them were published in the book entitled "Electrical Designs." Chapters X to XVIII inclusive, however, have not previously appeared in book form, and all of the direct-current designs herein described have been revised in accordance with the changes in the practice of dynamo and motor design which have occurred since their first publication.

The majority of the designs were prepared with a view of reducing to the simplest degree the facilities necessary for the construction of the machines, rather than to secure the most graceful outlines or best efficiency.

Chapters XIX to XXII inclusive describe designs by Mr. J. C. Brocksmith which were previously described in issues of the *American Electrician* that are now out of print. These were also reprinted in "Electrical Designs," which is superseded by the present book and three others now in press. The other volumes are devoted, one to electrical instruments, telephones and similar light constructions, another to heavier electrical apparatus other than dynamos and stationary motors, and the third to gas engines and other machinery not involving electrical construction. These volumes will contain all of the material that appeared in "Electrical Designs," excepting that contained by the present book, together with much additional matter not heretofore printed in book form.

C. P. P.

NEW YORK, December 1, 1905.

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DESIGNS FOR SMALL DYNAMOS AND MOTORS

CHAPTER I

ONE-SIXTH HORSE-POWER MOTOR WITH DRUM ARMATURE

In preparing this design and those which follow, it has been assumed that any one who is sufficiently interested in the subject to undertake the construction of a motor or dynamo will be sufficiently familiar with electro-mechanics to exercise individual judgment in the matter of fitting the various parts, and also in the design and construction of brush holders, terminal blocks, and such other parts as are not of controlling importance in the electrical design of the machines. Detailed descriptions of these parts will, therefore, not be given; the reader may easily inform himself concerning these, if necessary, by inspecting a finished machine of almost any type, or by reference to any good text-book.

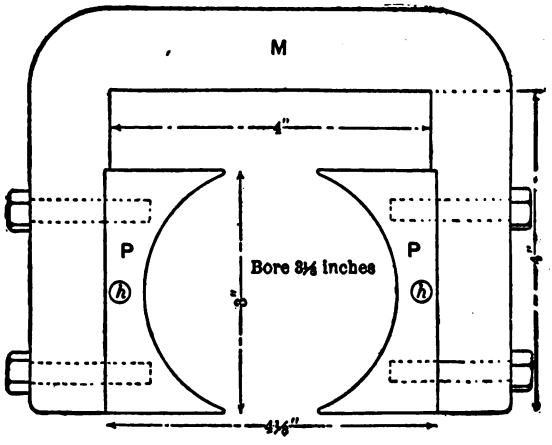

Fig. 1

The accompanying sketches are intended to serve as working drawings in the construction of a $\frac{1}{6}$ horse-power motor, for operation upon a 110-volt direct-current circuit. In Figs. 1 and 2, *M* is the field magnet, consisting

of a bar of wrought iron or mild steel 3 ins. wide and 1½ ins. thick, bent into the shape shown; the inner surface of each limb is machined smooth a distance of three inches, forming shallow mortises to receive the pole-pieces, *P P*, which are secured by ¼-in. cap screws passing through the magnet limbs. The pole-pieces, *P P*, are of gray cast iron, and should be finished on all sides to remove the scale as well as to improve the appearance of the completed machine. The magnet, *M*, might be made to look neater by touching up its sides on a coarse emery wheel; it should be well annealed after bending and finishing.

Two holes, *h*, *h*, are bored through the pole-pieces, after these are fitted to the magnet, but before the armature chamber is bored out. These holes are 17-64 in. diameter, and they must be 3¾ ins. apart, center to center, and equidistant from the center of the armature chamber; if the magnet limbs conform strictly to the measurement given from face to face of the finished part of the limbs, the centers of the holes, *h*, *h*, will each be 3-16 in. from the joint between the magnet and the pole-pieces. In these holes are to be inserted ¼-in. iron or steel rods 7¼ ins. long, threaded at each end a distance of ⅜ in. Fig. 2, which gives a plan view of the

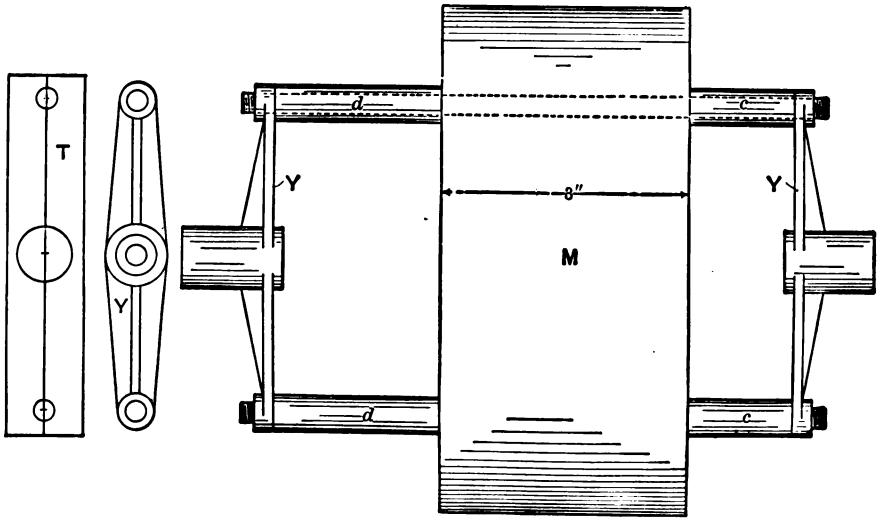

FIG. 2

magnet and the journal yokes, *Y*, *Y*, shows the function of these rods; they support the yokes and carry distance-pieces, *c*, *c*, *d*, *d*, made of brass tubing just large enough to slip over the rods, and having ⅛-in. walls. The pieces, *c*, *c*, are 1⅜ ins. long, and *d*, *d*, are 2⅛ ins. long. The yokes are held in place by brass nuts, not shown in Fig. 2.

The journal yokes, *Y*, *Y*, are alike. They are of cast brass, $\frac{1}{8}$ in. thick, with a stiffening rib $\frac{1}{8}$ in. thick, on each side of the journal box. The inner end of one box should be trued up to receive the brush arm or quadrant. The yokes may be much more easily and accurately fitted if a steel template is used. This may be cheaply provided by taking a piece of flat steel, 1 in. wide and $4\frac{1}{2}$ ins. long, scribing a straight line approximately down the center, and drilling three holes as shown by *T*, Fig. 2, the center one 11-16 in. and the others $\frac{1}{4}$ in. in diameter. After the box is bored, mount it on a mandrel and turn down the inner end to fit the center hole in the template *T*, and at the same time face up the ends of the yoke where they are to touch the distance-pieces; put the template on the end of the box and scribe the positions of the $\frac{1}{4}$-in. holes on the ends of the yoke. This template should also be used to fix the distance apart of the holes, *h*, *h* (Fig. 1). The boxes are bored out 9-16 in. in diameter and fitted with bushings of $\frac{1}{4}$ in. bore and 1 in. long; oil grooves should be cut at each end of the box and provision made for taking out the oil. Oil cups may be used to feed the bearings.

After the yokes are fitted the frame may be centered in a lathe as follows, for boring out the pole-pieces. Take a piece of $\frac{5}{8}$-in. round machinery steel 11 ins. long, and make the shaft *S* (Fig. 3); the distance from *e* to *g* is $3\frac{1}{4}$ ins. and the diameter there is $\frac{3}{8}$ in.; from *g* to *i* is 3 11-16 ins. and the diameter $\frac{1}{2}$ in.; from *i* to *j* is 1 1-16 ins. and the diameter $\frac{5}{8}$ in.; from *j* to *k* is 3 ins., and the diameter is $\frac{3}{8}$ in. Turn the ends of the shaft down to a point, like that of a lathe center; put it in the boxes, bolt the yokes in place, and then put the frame on the lathe carriage, adjusting it until the sharp ends of the shaft are in exact line with the lathe centers. Bolt the motor down in this position, remove the yokes and shaft, and bore out the pole-pieces. The ends of the shaft should afterwards be squared off, care being taken to cut exactly $\frac{1}{2}$ in. off each end, leaving the shaft 10 ins. long.

The armature (Fig. 3) is built up of iron discs 3 ins. in diameter and not more than 1-32 in. thick; there are twelve slots, each 3-16 in. wide and $\frac{3}{8}$ in. deep. These may be punched in each disc separately, if a stamping press is available, or they may be milled after the discs are assembled on the shaft. If the slots are milled the discs should be taken off the shaft afterwards and the burrs dressed off, care being taken to reassemble them exactly as they were when the slots were milled; this may be accomplished by taking a very slight cut with a metal saw along the top of one tooth, using the mark as a guide to get the proper slots together. In order to get them in exact alignment, a rectangular bar of metal should be made to fit snugly in one slot before taking the discs off; when they are put back this bar is inserted in the slot to which it was fitted and the

nut is set up hard. End plates, *W W*, of brass, 2 ins. in diameter and 3-16 in. thick, serve to prevent the end discs from buckling when they are compressed. A nut (not shown), fitted to the thread which begins at *g* on the shaft, serves to clamp the discs, which are held at the other end by the shoulder, *i ;* no key is necessary to prevent the discs from turning on the shaft in so small a machine, but it is essential that they should be clamped as tightly as a fairly strong man can clamp them, using a six-inch wrench on the nut. The shaft may be held in a pipe vise between *i* and *j* when setting up the nut; the nut should be made of very hard bronze metal in preference to steel, as the latter attracts magnetic lines of force and is liable to heat.

The commutator may be made as shown in the sketch, or according to any other modern plan, a number of which were described in the

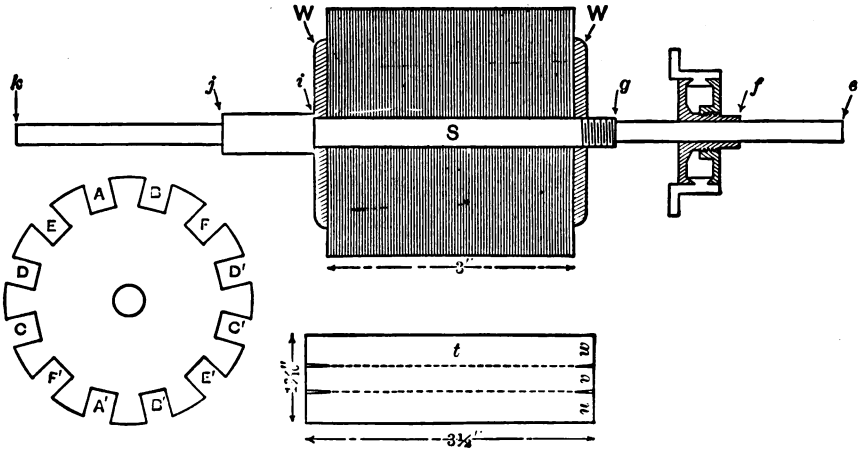

FIG. 3

American Electrician for July, 1896. The only essential features are the space along the shaft which must not exceed ¾ in., the width of face, which should not be less than ½ in., and the number of segments, which must be 24. The commutator here shown is intended to be secured to the shaft by a small steel set-screw through the hub or boss at the front; the end of this hub, *f*, must be 1¼ ins. from the end of the shaft. Extreme care must be taken to insulate the segments from the shell as well as from each other; mica is the only reliable material for this purpose. Carbon brushes ½ in. wide and ¼ in. thick should be used.

The armature core is next prepared for winding. Cut four discs of heavy drilling (so-called twilled muslin), 2¼ ins. in diameter, with a ⅜-in. hole in the center; varnish the ends of the armature core with shellac and

varnish two of the cloth discs, each on one side; thread them on the shaft, one at each end, with the varnished sides next to the core, and press them tightly on the core. While the varnish is hardening cut 24 pieces of drilling the shape of *t* (Fig. 3); cut two slits ¼ in. long in each end, 9-16 in. from each side, and 3-16 in. from each other; varnish the strips on one side, and when nearly dry bend them along the dotted lines so as to form troughs, with the varnish inside the trough. Varnish the outside of each trough and the walls of the slots in the core; put two troughs in each slot and turn the flaps, *u*, *v*, *w*, flat against the end of the core, applying enough fresh shellac to hold them down. Then put on the two remaining end discs of cloth, first varnishing the sides next to the armature; after they are in place varnish the outsides and put the core in an oven to bake, being careful that the oven is not hot enough to scorch the cloth. A temperature of 130 degs. Fah. is sufficient. After baking, tape the shaft

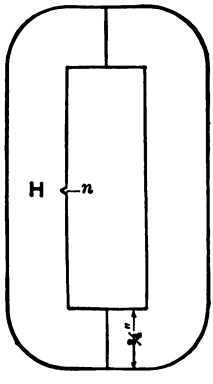

FIG 4

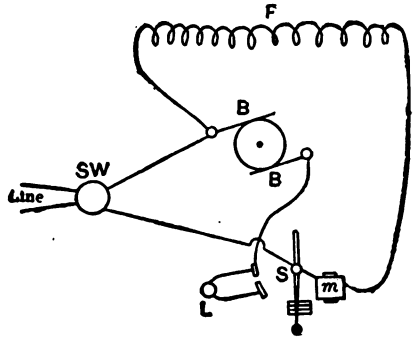

FIG. 5

thoroughly from *i* to *j*, and from the other end of the core to where the commutator will come.

The coils consist each of 20 turns of No. 24 double-silk-covered wire, wound 5 turns wide and 4 deep in the slots, but spread out as flat as possible across the heads. Wind coil No. 1 in slots, *A A'*; coil No. 2 in *B B'*; No. 3 in *C C'*; No. 4 in *D D'*; No. 5 in *E E'*, and No. 6 in *F F'*. Coil No. 7 goes in *A' A*, on top of coil No. 1, but beginning on the opposite side of the core, as indicated by the lettering; No. 8 in *B' B*; No. 9 in *C' C*; No. 10 in *D' D*; No. 11 in *E' E*, and No. 12 in *F' F*. Coils 13 to 24 are wound on top of the first 12 coils in exactly the same order. After winding each coil bring the finishing end across to the slot where the starting end enters and twist the two lightly together. When all the coils are on

untwist the coil ends and twist the last end of each coil to the starting end of the coil in the slot next to it on the right; these twisted ends go each to a commutator segment, in regular order.

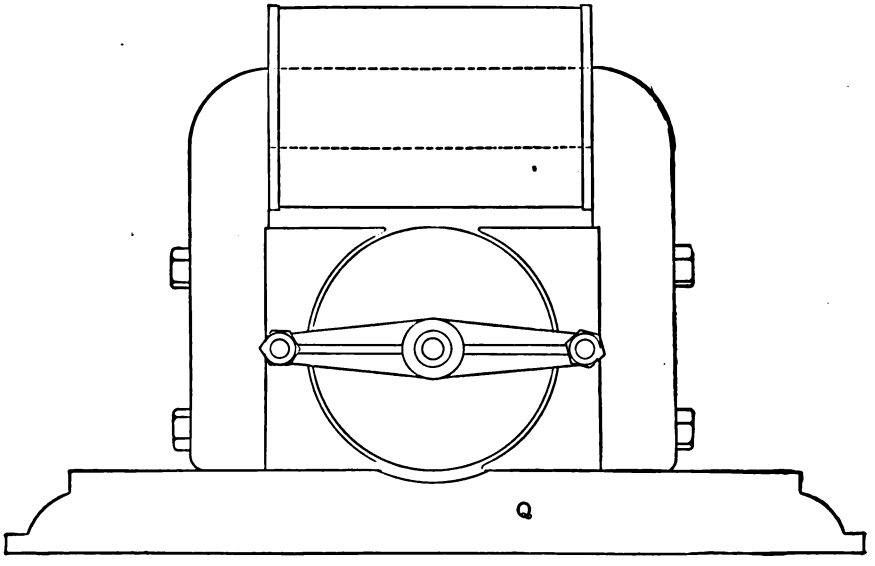

FIG. 6

The field magnet is easily made ready to wind by taping the horizontal part of the magnet, two layers deep, with varnished muslin and putting on two fiber heads. One of these heads is shown by *H* (Fig. 4). It is in two pieces, the seams being at the ends, and is cut from $\frac{1}{8}$-in. sheet fiber. The two halves may be clamped together on the core by means of a small brass wire drawn around the outer edge, laying in a shallow groove, the ends being twisted and cut close. The pole pieces should be removed before taping and putting on the heads, to facilitate these operations as well as the winding of the coil. One fiber head has a notch, *n*, half way of its inner long side, to enter the field wire. The coil consists of No. 28 single-cotton-covered wire, B. & S. gage, $\frac{3}{4}$ in. deep and the full length of the available space. At least 9,500 turns should be got on. The field winding is connected in shunt to the brushes, and it would be a good plan to provide a starting switch and resistance lamp connected up as shown diagrammatically by Fig. 5, where *F* is the field coil, *B B* the brushes, *L* a 32-candle-power, 100-volt incandescent lamp, *S* the starting switch, *m* a magnet, and *S W* a double-pole snap switch. This arrangement could be mounted on the base of the motor. Fig. 6 shows

the complete motor on a wooden base, *Q*, without the pulley; the latter may be any diameter between 1½ ins. and 2½ ins., with a 1-in. crown face or ½-in. grooved face. The motor is secured to the base by flat-head machine screws from below, entering the ends of the wrought iron and countersunk in the under side of the wood. This machine will stand a momentary overload of 100 per cent, and will work up to ¼ horse-power for half an hour at a time.

WINDINGS FOR BATTERY SERVICE

In order to adapt this motor for use in connection with a battery the following windings, etc., must be substituted for those specified above: The armature to be wound with six coils of No. 12 wire, each having twelve turns (three wide and four deep in a slot). The field wire will be No. 19, wound 17 layers deep and 83 turns in length. The commutator will have six segments, and should have a brush surface ¾ in. wide; copper brushes ⅜ x ½ in. should be used, the contact faces being cut to such a bevel as to present an area of ½ in. square at least. Connect the field winding in shunt with the armature, instead of in series as is usually done. This winding is for 6 volts. The machine thus wound will stand an armature current of 20 to 25 amperes.

CHAPTER II

ONE-SIXTH HORSE-POWER MOTOR WITH RING ARMATURE

IN Figs. 7 and 8 *M* is a wrought-iron magnet core, *P P* cast-iron pole-pieces, *C* the armature core, and *Y* the journal yoke. The magnet core, *M*, is made from a 1 in. x 4½ in. bar of commercial wrought iron bent to the shape shown. The faces of the arms are machined to a depth of 1-16 in., where the pole-pieces, *P P*, are attached, so as to form a magnetic joint of as low reluctance as possible. The pole-pieces are secured to the magnet arms by ¼-in. cap screws passing through smooth holes in the arms and tapped into the pole-pieces; the latter are of gray cast iron, and should be finished on all sides sufficiently to remove the scale. The magnet, *M*, might be improved in appearance by touching up its sides with a coarse emery wheel; it should be thoroughly annealed after bending and finishing. It will be noticed by reference to Fig. 8 that the ends of the magnet arms project slightly beyond the outer faces of the pole-pieces; this is done in order to furnish a guide for the flanges of the journal yoke arms. After fitting the pole-pieces to the magnet arms the complete magnet frame is bolted to the lathe carriage in position for boring out the pole-pieces; before this is done it is necessary to drill a hole through the back of the magnet to allow the boring bar to pass through, and also to form a seat for the rear bearing. This hole is 1 in. in diameter, and the magnet frame must not be allowed to move from its original position on the lathe carriage from the time the hole is drilled until all the circular tooling on it is accomplished.

After drilling the hole in the back of the magnet adjust the boring bar and bore the armature chamber out, 4 11-16 ins. in diameter. Next adjust the boring tool so that it will scribe on the ends of the magnet arms arcs of a circle 6 ins. in diameter; then cut away the wrought iron inside the scribed marks, down flush with the pole-pieces, as shown in Fig. 7, forming recesses for the flanges of the journal yoke. The yoke and box are cast in one piece of brass or other non-magnetic composition; the shell of the box is 1¼ ins. long, and projects ¼ in. beyond the inner face of the yoke; the outer diameter of the shell is 1 in., and it is bored out to

$\frac{3}{4}$ in. inner diameter and bushed to $\frac{3}{8}$ in. The yoke and arm portions are 3-16 in. thick, with a $\frac{1}{8}$-in. stiffening rib on each side of the box, and the arms taper from 1 in. wide at the flanges to about $\frac{1}{2}$ in. near the box. The flanges are 2 ins. long, $\frac{3}{4}$ in. wide, and $\frac{1}{8}$ in. thick after facing; the arms, beyond the bends, are sufficiently long to make the distance from the face of the pole-piece to the inner face of the yoke 2 ins. After boring the box it is mounted on a stiff mandrel and the surfaces of the flanges that go next the magnet are faced up true; next, the outer edges of the flanges are skimmed off until the yoke fits snugly between the curved edges of the recesses previously cut in the ends of the wrought-iron magnet. Care must be taken in making the pattern for the yoke that the inner edges will not project inward beyond the bore of the pole-pieces. The yoke is fastened to the pole-pieces by screws, as indicated in Fig. 7.

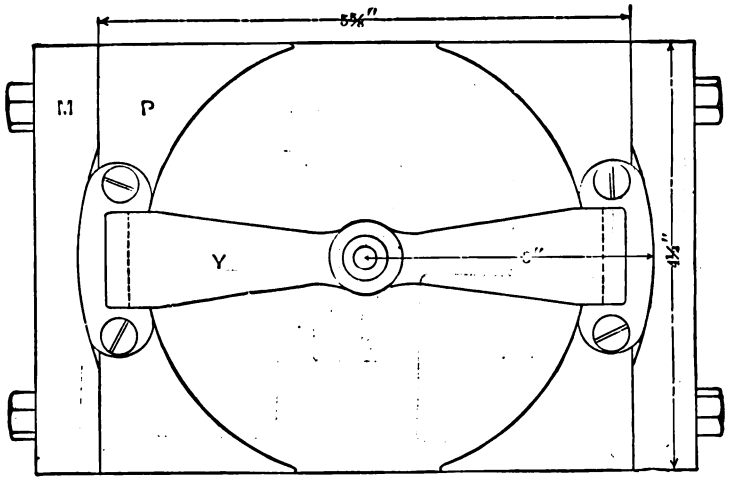

FIG. 7

The rear bearing, *J*, is a little peculiar in construction. The box portion is similar to that part of the yoke, but it is cast with a flange, *f*, 1 in. from the farthest end of the shell, which is 1½ ins. long. A collar, *n*, is fitted to screw onto the outer end of the shell, which is threaded for that purpose. The shell is turned down outside to fit snugly in the hole drilled in the back of the magnet, and when it is inserted in the hole the collar, *n*, is put on and screwed up tight. This box, like the front one, is bushed to $\frac{3}{8}$-in. bore. The drawing shows the flange, *f*, and collar, *n*, countersunk in the metal of the magnet; this will not be necessary if the magnet is smoothed up with an emery wheel, as above suggested, the object in countersinking being to provide smooth, true bearing surfaces for the flange and collar.

The armature core, spider, and shaft are shown, partly in cross-section, by Fig. 9. The core is built up of low carbon steel rings, $4\frac{1}{2}$ ins. outside diameter and $2\frac{1}{2}$ ins. inside, not more than 1-32 in. thick; these are assembled on a brass drum, shown by Fig. 11, which should be $2\frac{5}{8}$ ins. outside diameter before finishing, so that it may be turned down to exactly fit the inner circle of the armature rings; the wall of the drum is $\frac{1}{8}$ in. thick after finishing, and there are four equidistant projecting lugs, *l*, $\frac{1}{2}$ in. long, on each end, by which the drum is secured to the spider (see Figs. 9 and 10). The rings forming the core, *C* (Fig. 9), are compressed and held on the drum, *r*, by two brass washers, *w*, *w*, 3-16 in. thick and $3\frac{5}{8}$ ins. outer diameter, which screw onto the ends of the drum. The core, when compressed, is $1\frac{3}{4}$ ins. long, and has 24 slots 3-16 in. wide and 7-16 in. deep; the washers, *w*, *w*, must be set up as tight as the threads will stand.

The spider, *s* (Figs. 9 and 10), is made of brass, and consists of a hub ($\frac{3}{4}$ in. diameter, 2 ins. long, and $\frac{5}{8}$ in. bore) and four arms having T-

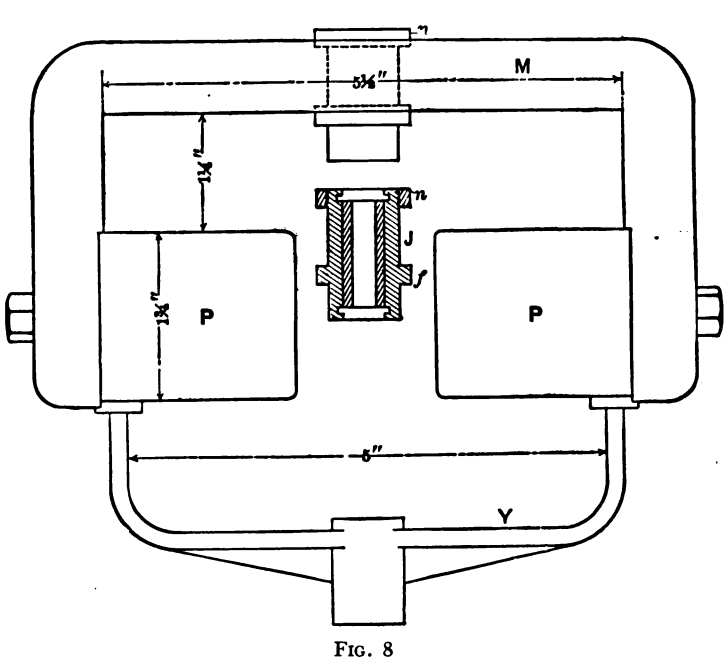

FIG. 8

shaped ends, the wide part or heads of which project beyond the arms and hub at each end, the length of these heads being $2\frac{7}{8}$ ins. and their width $\frac{3}{8}$ in. The heads of the spider arms are turned off to fit very closely inside the drum, *r*, which is mounted on the spider in such a position as to bring the spider arms in alignment with the lugs, *l*, of the

drum; screws through the spider arms into the lugs hold the drum and spider together.

The shaft, *S*, is 8½ ins. long; the portion *j* is 1⅛ ins. long and ⅜ in. diameter; *k* is 1 in. long and 7-16 in. diameter; the part passing through the core is 3 ins. long and ⅝ in. in diameter; *m* is ⅜ in. long and 7-16 in.

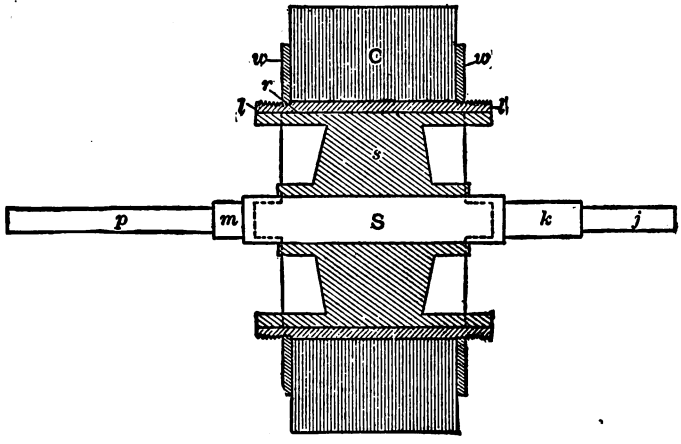

FIG. 9

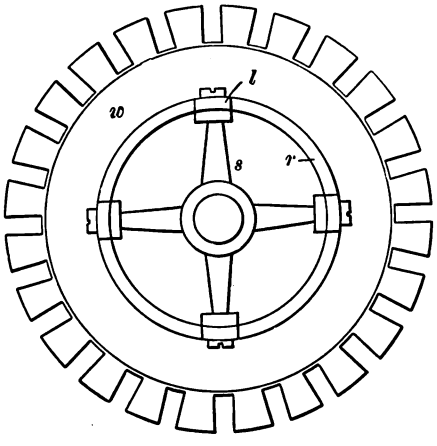

FIG. 10

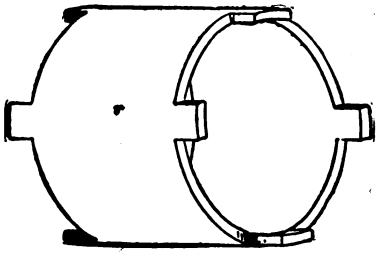

FIG. 11

diameter; and *p* is 3 ins. long and ⅜ in. diameter. The spider, *s*, may be secured to the shaft by a key or a set-screw; the set-screw is sufficient in so small a machine. The commutator (not shown) must not be more than ¾ in. over all, along the shaft; it must have ½ in. brush surface and 24 segments; other details may be made to suit the will of the builder. The

front end of the commutator must be not less than 3-16 in. from the shoulder where *j* and *k* join.

The armature is next prepared for winding by removing the drum and core from the spider and insulating the ends and interior of the core and the walls of the slots. Cut four rings of heavy drilling of a size to cover the washers, *w*, *w*, and the ends of the drum, *r* ; varnish two of them on one side with shellac, and apply them to the ends of the armature body. While these are hardening cut forty-eight strips of drilling 1⅛ ins. wide and 2¼ ins. long; in each end of each of these cut two slits ¼ in. long parallel with the sides, and located 15-32 in. from each side of the strip. Varnish these on one side, and when nearly dry fold them into troughs to fit the slots, two troughs to a slot, one within the other; fold them so that the varnish will be on the inside of the trough.

When these are dry varnish the slots and the outsides of the troughs and put the latter in the slots, bending the ends flat against the core and securing them there with a little fresh varnish. Then varnish the ends of the core (two cloth rings being on them), and one side of the two remaining rings of drilling; put these rings on top of the first ones, varnish them on the outside, and put the core in an oven to bake. The armature coils consist of No. 24 double-silk-covered wire, wound 5 turns wide and 14 layers deep. Before winding them four strips of wood 3 ins. long, ⅜ in. wide, and ½ in. thick should be screwed to the inner wall of the brass drum, in line with the lugs, *l*, so as to preserve the spaces for the four arms of the spider. A double thickness of drilling should also be applied to the interior of the drum to insulate the coils from it. The connections are the simple Gramme ring arrangement.

The field winding is necessarily divided into two coils, on account of the rear bearing passing through the magnet. Each coil consists of No. 28 double-cotton-covered wire, wound ⅝ in. deep and 1¾ ins. long; the two coils are connected in series with each other and in shunt to the brushes. Heads of hard fiber ⅛ in. thick should be used to protect the ends of each coil; one of these is shown by *H* (Fig. 12), but the width should be ⅝ in. instead of ¾ in. as marked.

It is in two pieces, the seams being at the ends, and is cut from ⅛ in. sheet fiber. The two halves may be clamped together on the core by means of a small brass wire drawn around the outer edge, laying in a shallow groove, the ends being twisted and cut close. The pole-pieces should be removed before taping and putting on the heads, to facilitate these operations as well as the winding of the coil. One fiber head has a notch, *n*, half way of its inner long side to enter the field wire. The pole-pieces should, of course, be removed before winding the field coil, and the magnet core should be wrapped with two layers of varnished drilling

where the coils are to go. The entering end of each coil should be remote from the journal, and this means that the magnet must be turned end for end after one coil is wound, or else the two coils must be wound in opposite directions in order that the free ends at the center of the magnet may be connected together. It is advisable to provide a starting switch similar to the one shown diagrammatically by Fig. 13, where *F* is the field coil; *B B* the brushes; *S* the starting switch lever; *L* a 32-candle-power 110-volt lamp; *M* a magnet, and *SW* a double-pole snap switch.

The motor is intended to be mounted on a wooden base-board 8 ins. x 8 ins., a cleat 3 ins. wide and 7-16 in. thick being put under the pole-pieces so as to clear the field coil. Bolts from beneath, tapped into the

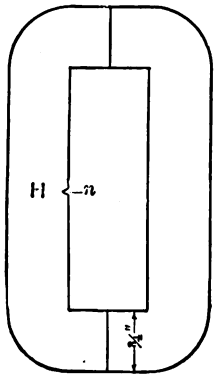

FIG. 12

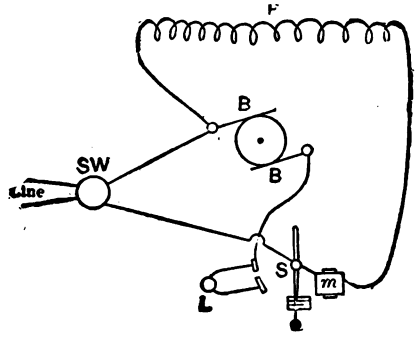

FIG. 13

magnet and countersunk in the under side of the base, should be used to hold the motor on the base. The pulley may be any diameter from 1 in. to 3 ins. by 1 in. face, if crowned, or ½ in. if grooved.

WINDINGS FOR BATTERY CURRENT

For 6-volt battery current the armature should be wound with 12 coils of No. 13 wire, each coil having 16 turns and occupying two (adjacent) slots. The field wire should be No. 18, wound 12 layers deep and 38 turns long in each coil; the two coils containing 912 turns in all. The commutator must have 12 segments and a brush surface ¾ in. wide; copper brushes ⅜ x ½ in. should be used, the contact faces being cut to such a bevel as to present a surface at least ½ in. square each. The field winding is to be connected in shunt to the brushes, instead of in series as is usually the practice in battery motor construction. This winding is for 6 volts at the terminals; the current required will depend upon the work done; the machine is capable of standing an armature current of 20 to 25 amperes.

CHAPTER III

ONE-FOURTH HORSE-POWER MOTOR WITH DRUM ARMATURE

FIG. 14 represents the field magnet and Fig. 15 one of the journal yokes of a $\frac{1}{4}$ horse-power 110-volt motor, with a drum armature. The magnet is of the familiar single-coil type. The core is of round machinery steel, $2\frac{1}{4}$ ins. in diameter and 9 ins. long over all. The ends are turned tapering as indicated by dotted lines, to insure intimate contact with the yokes; the taper is from the full diameter to $1\frac{3}{4}$ ins., and begins 2 ins. from each end. The pole-pieces are of cast iron. Fig. 16 gives a plan view and a face view of one pole-piece, from which all the essential dimensions may be obtained. The arms which support the journal yokes are cast solid with the pole-pieces, and their horizontal thickness tapers from $\frac{1}{2}$ in. at the pole-piece to $\frac{1}{4}$ in. where the yoke is bolted on.

In fitting the magnet frame together the best procedure is to bore the tapered holes in the lower part of each pole-piece and turn the ends of the magnet core to the same taper, but just a trifle large; then dress each taper down very gradually with a fine file (the core being run in a lathe) until the pole-piece can be pushed on by hand far enough to bring the end of the core within 1-32 in. of the back surface of the cast iron. The pole-pieces and ends of the core should be punch-marked, so as to insure finally mounting each pole-piece on the end to which it was fitted. After dressing down the ends of the core as above described, drill and tap in each end a hole for a $\frac{1}{2}$-in. machine screw, the purpose of which will be apparent by glancing at the right-hand end of the magnet in Fig. 14, where *C* is a four-armed claw or spider with a hole through the center where the arms intersect. The arms are $\frac{1}{4}$ in. thick, measured at right angles to the bolt, and taper from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. thick measured parallel with it. One of these spiders is used at each end, though the drawing shows it at only one end of the machine.

After drawing one pole-piece home solid by means of its spider and bolt, slip the other pole-piece on loosely and clamp the pole-pieces lightly

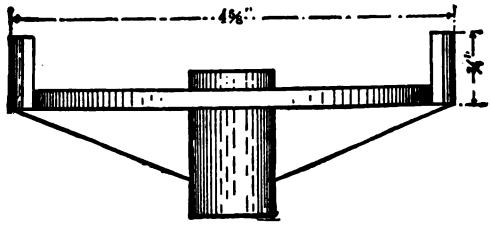

FIG. 15

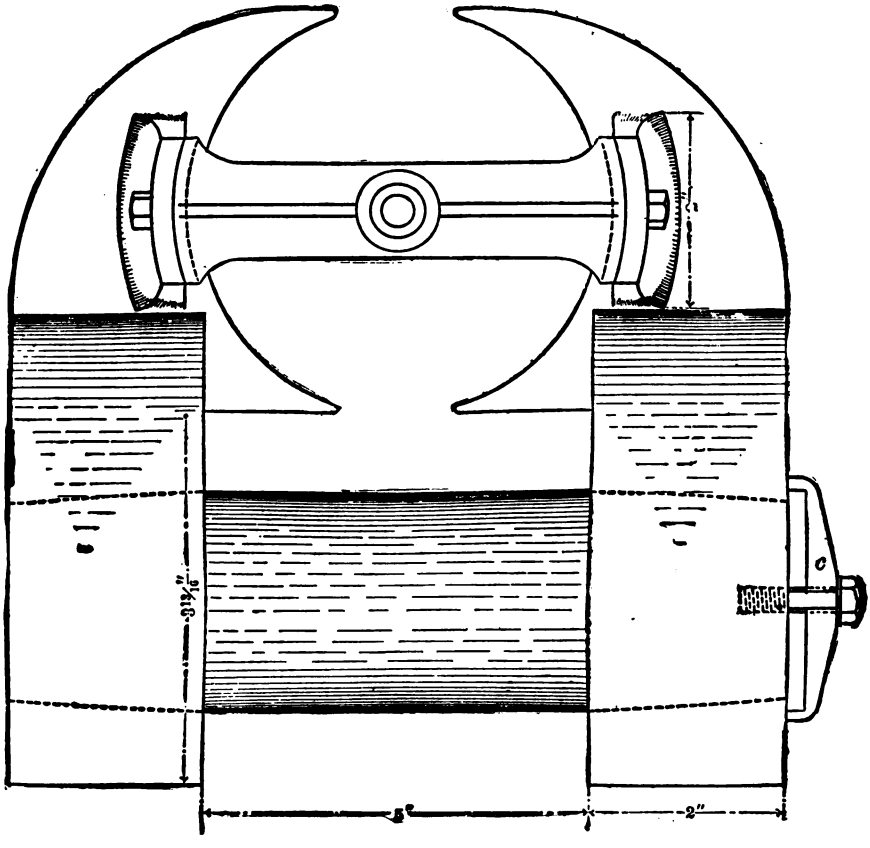

FIG. 14

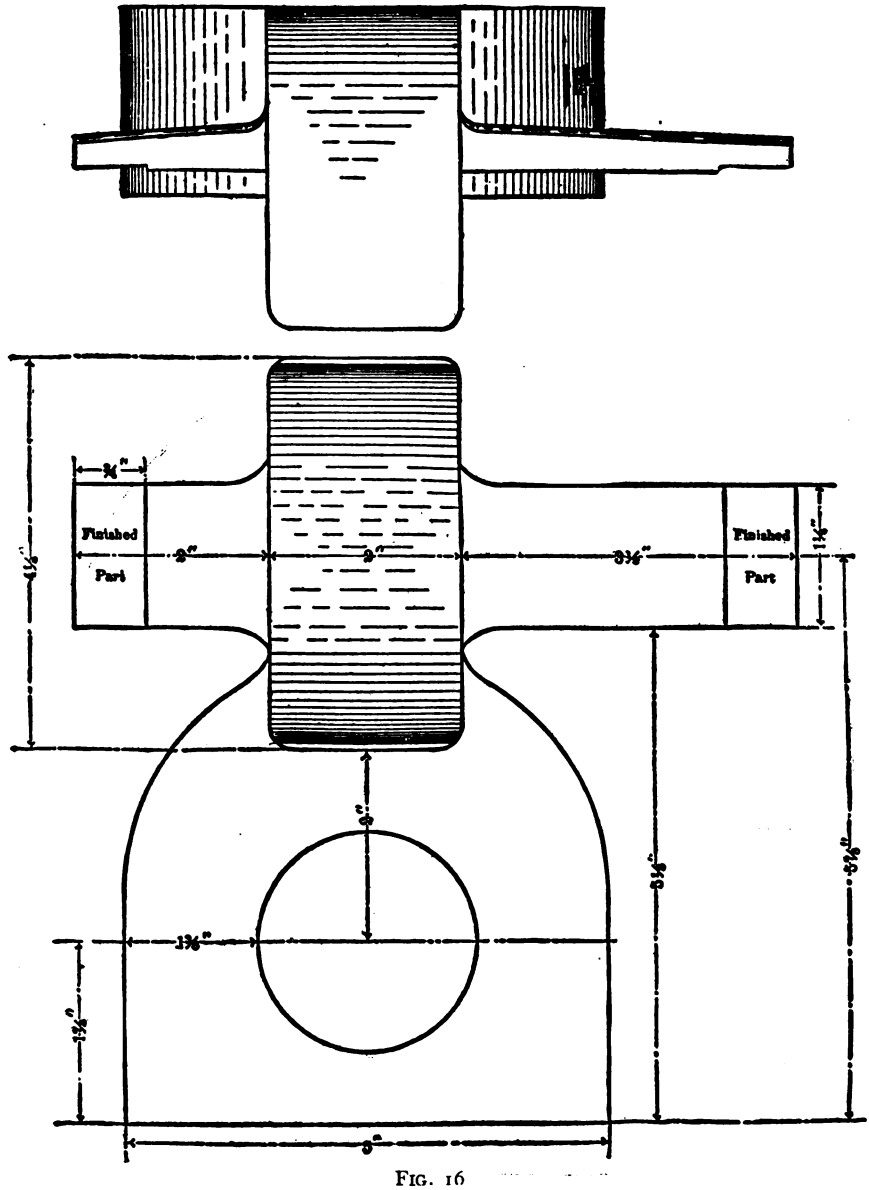

FIG. 16

between two iron plates with planed surfaces, applied between the journal arms, so as to keep the four horns of the pole-pieces in alignment; then force the second pole-piece home by means of its bolt and spider, and clamp the horns hard between the iron plates. The bottom surfaces of the cast-iron pieces should then be trued up on a planer or shaper and the clamps taken off the pole-piece horns.

The next operation is boring the armature chamber and the seats for the journal yokes. The armature chamber bore is 4 3-16 ins.; the seats for the journal yokes, marked "finished part" in Fig. 16, are bored or cut to $4\frac{5}{8}$ ins. diameter, and this must be done before the position of the machine is disturbed after boring the armature chamber. This completes the machine work on the magnet, except the bolt holes.

The journal yoke may be made of brass or any composition metal.

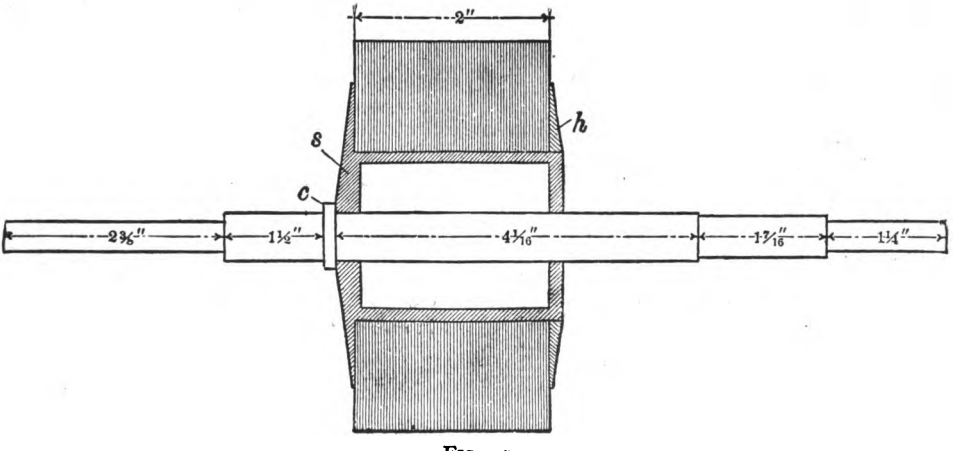

FIG. 17

The bar is 3-16 in. thick and $1\frac{1}{8}$ in. wide, except near the ends, where it flares to correspond with the width of the arms. At each end is a right-angled lug, $\frac{1}{8}$ in. thick after machining; these lugs fit the seats in the ends of the iron arms, and the yokes should be fitted to the magnet immediately after finishing the machine work on the latter, and before it is taken apart to put on the coil. The box portion is $1\frac{1}{2}$ ins. long over all, 3-16 in. of its length being on the inside of the yoke and $1\frac{1}{8}$ ins. on the outside. As shown by the plan view of the yoke in Fig. 15, there are stiffening ribs starting flush near the ends of the yoke and attaining a width of $\frac{3}{4}$ in. at the box; these are 3-16 in. thick. The box is 1 in. in outer diameter, and bored to $\frac{3}{4}$ in. inside; it is bushed to $\frac{1}{2}$ in. diameter. These latter dimensions, excepting the final inside diameter of the bushing, may be varied

to suit individual ideas, as may also the design of the box. The only essential measurements are those of the yoke-bar, the length of the box and the bore of the journal bushing. The journal yokes are held in place by $\frac{1}{4}$ in. cap screws passing through the iron arms and tapping into the lugs of the yokes.

Figs. 17, 18, and 19 show the shaft and armature core (the latter in cross-section), an armature disc, and the shell and head. The discs are of low-carbon annealed steel 4 ins. outside diameter with a $1\frac{1}{4}$-in. hole in the center and a 3-16-in. key-seat, annealed after punching and key-seating; there are eighteen slots 3-16-in. wide and $\frac{1}{2}$ in. deep. The shell and one head are cast in one piece (of brass), and consist of a barrel $1\frac{1}{4}$ ins. outside diameter (when finished) and 2 ins. long, with a head, *s*, at one end, $3\frac{1}{8}$ ins. in diameter and tapered in thickness from $\frac{1}{4}$ in. near the center to 1-16 in. at the periphery; at the opposite end of the barrel is a cross-bar $\frac{1}{3}$ in. thick, cast with the barrel and of the shape shown, being $\frac{3}{8}$ in. wide where it joins the barrel and $\frac{3}{4}$ in. at the center. A $\frac{1}{2}$-in. hole is drilled in the center of this cross-bar and another in the center of the head, *s*, at the other end of the barrel; the shell is mounted on a mandrel, the barrel turned down to fit the hole in the armature discs, and both sides of the head faced off smooth. A 3-16 in. key-seat $\frac{1}{8}$ in. deep is cut in the barrel so as to come in the center of one end of the cross-bar, as shown; a 3-16-in. x $\frac{1}{4}$-in. parallel key is laid in the key-seat, and the discs threaded on the barrel and compressed against the head by the collar, *h*, and two bolts (not shown) passing through the collar and inside the barrel, and tapping into the head at the other end. This collar, *h*, is of brass, $3\frac{1}{8}$ ins. in diameter and tapering from 3-16 to 1-16 in. in thickness when finished. The opening in the center should fit the outline of the cross-bar on the end of the barrel at least closely enough to prevent the collar from shifting under stress of centrifugal force; the collar must be finished up smooth on both sides. A disc of insulation should be put on next to the brass head before the iron discs are put on, and another insulating disc should go between the last iron disc and the clamping collar, *h*.

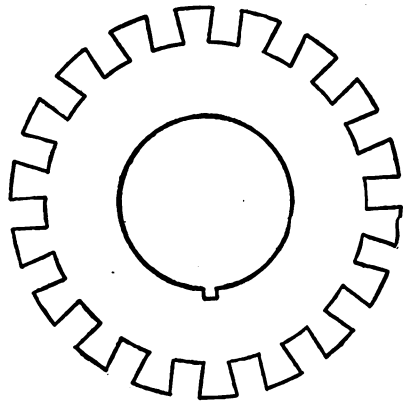

FIG. 18

If the slots are cut in the core with a milling machine the discs must all come off the barrel to have the burrs removed, and also be reannealed;

the key-seat will insure their returning in the original angular position. It is much better to have discs with the slots punched before the first annealing. The shaft is 10¾ ins. long over all; ¾ in. in diameter in the largest part, ⅝ in. where the commutator goes and ½ in. in the journals. A 1-16-in. x ⅛-in. collar, *c*, is shown back of the armature, the purpose of which is merely to "locate" the armature shell; it is not absolutely necessary, however, and may be left off if desired. The easiest way to provide for it is to make the shaft of 1-in. stock, leaving the original metal to form the collar when turning the shaft to proper diameter. The armature shell may be keyed to the shaft or pinned obliquely through the thick part of the head; it must be positively secured by some such means.

The commutator shell must be bored to fit the ⅝-in. portion of the shaft, and must not exceed 1¼ ins. along the shaft. The lugs where the wires are attached to the segments may project toward the armature ⅛ in. or so. There must be 36 segments, and a diameter of 2 ins. is recommended. The quadrant carrying the brush holders should be fitted to the inner end of the journal box, and carbon brushes not smaller than

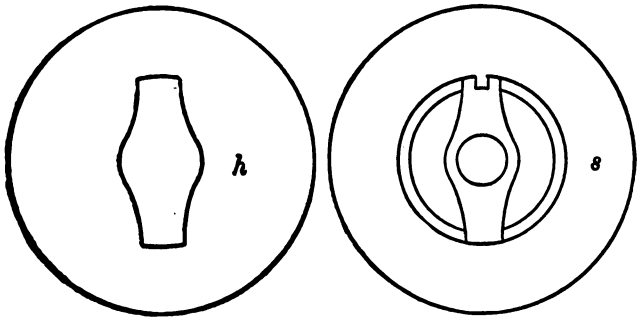

FIG. 19

¼ in. x ½ in. (one on each side) on the contact surface should be used. If the machine be used as a dynamo (it will maintain five or six 110-volt lamps) metal brushes of the same surface should be used to reduce the resistance of the brush contact.

The field coil consists of No. 27 single-cotton-covered wire, wound to an outer diameter of 3⅝ ins. After the magnet is fitted as described in the beginning of this chapter it is taken apart and two circular magnet heads of fiber ⅛ in. thick and 3¾ in. outer diameter are put on with a driving fit, care being taken that the distance along the core from outside to outside of the heads corresponds with the distance between the pole-pieces when the whole is assembled. A groove must be cut on the inner face of one

head from the center to the outer edge in order to lead out the starting end of the field wire, and this must be covered with two layers of oil paper to prevent short-circuiting the successive layers of the coil. The core must be insulated with three layers of shellacked muslin between the heads and the field wire put on evenly, care being taken not to "spread" the heads; the winding must be very carefully done so as to get in as many turns as possible in order to keep down the heat loss.

After winding the coil and securing the ends one pole-piece is put on solid and the other one slipped on until it begins to bind, when the journal yokes must be inserted between their arms and the bolts put in as far as possible without jamming. Then by tightening up the journal yoke bolts and the pole-piece bolt together, being particular never to draw the yoke bolt hard against the arm, the frame will come together in its original position. As an additional precaution it may be set on a true plane surface, and if the base of the loose pole-piece gets out of alignment tap the horn lightly until the frame is true on the bottom. The magnet frame must be provided with a non-magnetic base; hard wood is as good as anything, the frame being secured by flat-head brass machine screws from below, two in each casting, countersunk in the wood.

The armature winding is divided into 36 coils, each having 16 turns of No. 23 double-cotton-covered wire, 4 turns wide and 4 turns deep in the slot. The slots must be insulated with troughs of muslin and mica, or preferably flexible micanite, 0.03 in. thick. The troughs are easily made by cutting the material into strips $2\frac{1}{2}$ ins. long by $1\frac{1}{4}$ ins. wide, and slitting the ends so as to permit the projecting portion of the trough to be folded back flat against the core. Before putting in the troughs a disc of heavy drilling $3\frac{1}{4}$ ins. in diameter should be secured to each end of the core by means of varnish, and the outer faces varnished and allowed to nearly dry. Then put in the troughs and put on two more muslin discs, varnishing the whole, and bake until thoroughly dry. Instead of winding each coil in diametrically opposite slots, take slots lacking one of being precisely opposite.

A good plan is to make a sketch of an armature disc and number the slots from left to right successively around the periphery. Then wind the coils as follows, the coil numbers indicating the order in which the coils are put on, not the order in which they are connected to the commutator.

COIL NO. —	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
COIL NO. —	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

STARTS IN SLOT NO. —	1	10	13	4	7	16	2	11	15	6	14	5	18	9	3	12	8	17
ENDS IN SLOT NO. —	9	18	3	12	15	6	10	1	5	14	4	13	8	17	11	2	16	7

Each pair of coils must be covered with muslin where they cross the

heads before the next pair is put on, and before coil No. 8 is wound on top of coil No. 1 in slot No. 1 the bottom coil must be insulated by a strip of micanite laid in the slot; this is true of every bottom coil.

After the winding is on, and before connecting up to the commutator, the band wires should be put on. Use No. 19 B. W. G. soft tinned-iron wire, known by hardware dealers as "white stove-pipe wire," for the bands, and put them on under as heavy pressure as possible without endangering the armature shaft. Two bands of eight turns each, $\frac{1}{2}$ in. from each end of the core, will suffice. A strip of mica between two strips of fullerboard must go under each band, and the bands should be soldered at intervals, not all the way around. Four tin clips located equidistantly, with a dab of solder at each, will give ample security.

Care must be taken in connecting up the armature winding to take the starting ends of the coils in proper succession to the commutator segments; the outer end of each coil goes to the segment on the right of the one to which the starting end is led.

The principal data for this machine are as follows:

TERMINAL E. M. F., 110 VOLTS

Armature current, normal	2 amps.
Magnetic flux per square inch:	
In field core	100,000 lines
In pole-pieces	43,500 "
In air-gap	28,000 "
In armature teeth	80,000 "
In armature core	62,000 "
Coefficient of leakage	1.4
Commercial efficiency (friction 10 p. c. estimated)	60%
Revolution per minute	2,000

CHAPTER IV

ONE-FOURTH HORSE-POWER MOTOR WITH RING ARMATURE

THIS machine has a field magnet of exactly the same design as the one last described, the only difference being in the dimensions. The instructions for fitting up the magnet shown by Figs. 14 and 15, therefore, apply to this one. The size of the magnet core and yokes shown by Fig. 14 also apply to this magnet. Figs. 21 and 22 give all of the dimensions for this magnet frame that differ from those of the previous one, excepting the bore of the armature chamber, which is 5 3-16 ins. instead of 4 3-16 ins. The lugs that support the journal yokes are set one inch wider apart than in the drum armature motor, and the seats for the ends of the journal yokes are bored or cut to $5\frac{5}{8}$ ins. diameter. As in the former case, this boring must be done before the frame is moved from the position it occupied during the boring of the armature chamber.

The journal yokes may be made of any metal except iron and steel. The bar is 3-16 in. thick and $1\frac{1}{8}$ ins. wide, except near the ends, where it flares to correspond with the width of the arms. At each end is a right-angled lug, $\frac{1}{8}$ in. thick after machining; these lugs fit the seats in the ends of the iron arms, and the yokes should be fitted to the magnet immediately after finishing the machine work on the latter, and before it is taken apart to put on the coil. The box portion is $1\frac{1}{2}$ ins. long over all, 3-16 in. of its length being on the inside of the yoke and $1\frac{1}{8}$ ins. on the outside. As shown by the plan view of the yoke, Fig. 22, there are stiffening webs starting flush near the ends of the yoke and attaining a width of $\frac{3}{4}$ in. at the box; these are 3-16 in. thick. The box is 1 in. in outer diameter, and bored to $\frac{3}{4}$ in. inside; it is bushed to $\frac{5}{8}$ in. diameter. Most of the dimensions of the yoke and box may be varied to suit individual ideas, as may also the design of the box. The only essential measurements are the length of the yoke-bar, the length of the box, and the bore of the journal bushing. The journal yokes are held in place by $\frac{1}{4}$-in. cap screws passing through the iron arms and tapping into the lugs of the yokes.

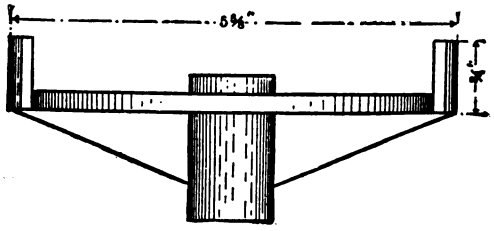

FIG. 22

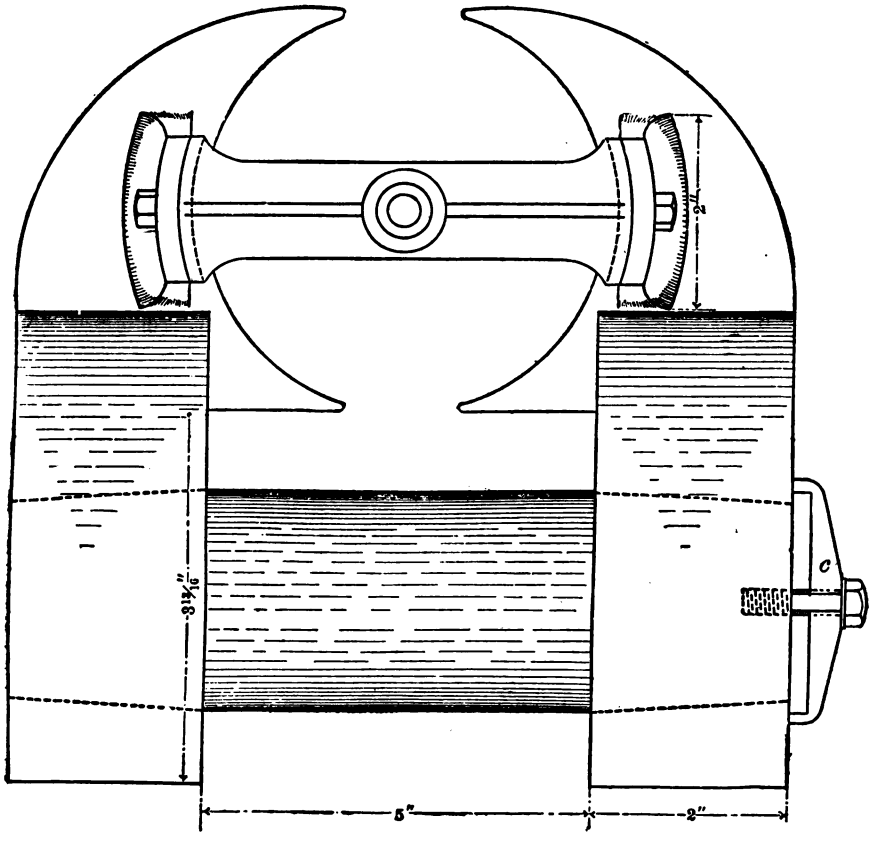

FIG. 20

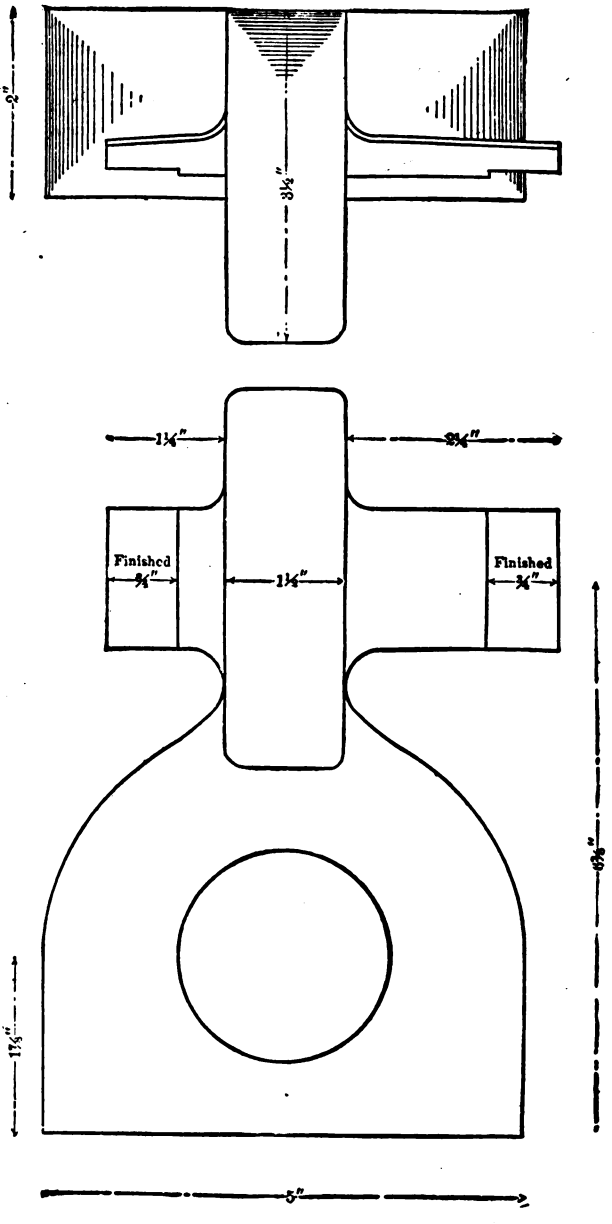

FIG. 21

The armature core, spider, and shaft are shown, partly in cross-section, by Figs. 23 and 24. The core is built up of low-carbon annealed steel discs 5 ins. outside diameter and $2\frac{5}{8}$ ins. inside, not more than 25 mils thick; these are assembled on a brass drum $1\frac{5}{8}$ ins. long (Fig. 25) which should be $2\frac{3}{4}$ ins. outside diameter before finishing, so that it may be

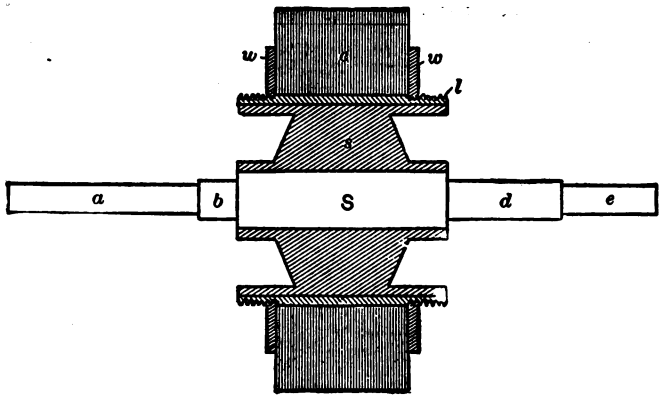

FIG. 23

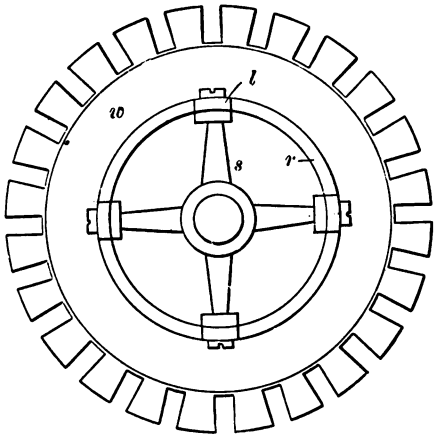

FIG. 24

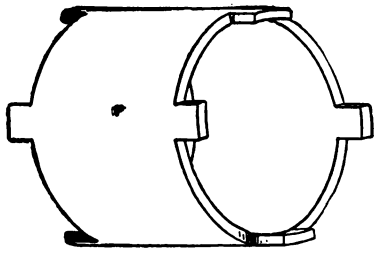

FIG. 25

turned down to exactly fit the inner circle of the armature rings; the wall of the drum is $\frac{1}{8}$ in. thick after finishing, and there are four equidistant projecting lugs, *l*, $\frac{3}{8}$ in. wide and $\frac{1}{2}$ in. long, on each end, by which the drum is secured to the spider (see Figs. 22 and 23). The rings forming the core, *c* (Fig. 23), are compressed and held on the drum, *r*, by two brass washers, *w*, *w*, 3-16 in. thick and $3\frac{7}{8}$ ins. outer diameter, which screw

onto the lugs and ends of the drum. The core has 24 slots $\frac{1}{4}$ in. wide and $\frac{1}{2}$ in. deep, and when compressed it is $1\frac{1}{2}$ ins. long. The washers, *w w*, must be set up as tight as the threads will stand.

The spider, *s* (Figs. 23 and 24), is made of brass, and consists of a hub ($\frac{7}{8}$ in. in diameter, $2\frac{1}{2}$ ins. long, and $\frac{5}{8}$ in. bore) and four arms having T-shaped ends, the wide part or heads of which project beyond the arms at each end, the length of these heads being $2\frac{5}{8}$ ins. and their width $\frac{3}{8}$ in. The heads of the spider arms are turned off to fit very closely inside the drum, *r*, which is mounted on the spider in such a position as to bring the spider arms in alignment with the lugs, *l*, of the drum; screws through the spider arms into the lugs hold the drum and spider together.

The shaft, *S*, is $8\frac{1}{4}$ ins. long; the portion *a* is $2\frac{1}{2}$ ins. long and $\frac{5}{8}$ in. in diameter; *b* is $\frac{1}{2}$ in. long and $\frac{7}{8}$ in. in diameter; the part passing through the core is $2\frac{1}{2}$ ins. long and 1 in. in diameter; *d* is $1\frac{1}{2}$ ins. long and $\frac{7}{8}$ in. in diameter, and *e* is $1\frac{1}{4}$ ins. long and $\frac{5}{8}$ in. in diameter. The spider, *s*, should be secured to the shaft by a key, the key-seat being located at the base of one of the arms. The front end of the commutator must be located not less than 3-16 in. from the shoulder where *d* and *e* join.

The armature is next prepared for winding by removing the drum and core from the spider and insulating the ends and interior of the core and the walls of the slots. Cut four rings of heavy drilling of a size to cover the washers, *w w*, and the ends of the drum, *r*; varnish two of them on one side with shellac, and apply them to the ends of the armature body. While these are hardening cut twenty strips of micanite cloth, 25-1000 in. thick, 1 5-16 ins. wide and 2 ins. long; in each end of each of these cut two slits, $\frac{1}{4}$ in. long, parallel with the sides and located each $\frac{1}{8}$ in. from the center of the strip. Varnish these on one side, and when nearly dry fold them into troughs to fit the slots; fold them so that the varnish will be on the inside of the trough.

When these are dry varnish the slots and the outsides of the troughs and put the latter in the slots, bending the ends flat against the core and securing them there with a little fresh varnish. Then varnish the ends of the core (two cloth rings being on them), and one side of the two remaining rings of drilling; put these rings on top of the first ones, varnish them on the outside and put the core in an oven to bake. The armature coils consist of No. 22 double-cotton-covered wire, wound 6 turns wide and 13 layers deep. Before winding them four strips of wood 3 ins. long, $\frac{3}{8}$ in. wide, and $\frac{1}{2}$ in. thick should be screwed to the inner wall of the brass drum, in line with the lugs, *l*, so as to preserve spaces for the four arms of the spider. A double thickness of drilling should also be applied to the interior of the drum to insulate the coils from it. The connections are the simple Gramme ring arrangement. Before connecting up to the

commutator the band wires should be put on. Use No. 19 B. W. G. soft tinned-iron wire, known by hardware dealers as "white stove-pipe wire," for the bands, and put them on under as heavy pressure as possible without endangering the armature shaft. Two bands of eight turns each, $\frac{1}{2}$ in. from each end of the core, will suffice. A strip of mica between two strips of fullerboard must go under each band, and the bands should be soldered at intervals, not all the way around. Four tin clips located equidistantly, with a dab of solder at each, will give ample security.

The commutator (not shown) must be bored to fit the $\frac{7}{8}$-in. portion, *d*, of the shaft, and must not exceed $1\frac{1}{4}$ ins. along the shaft; it must have a brush tread 1 in. wide. The lugs where the wires are attached to the segments may project toward the armature $\frac{1}{8}$ in. or so. There must be 24 segments, and a diameter of 2 ins. is recommended. The quadrant carrying the brush-holders should be fitted to the inner end of the journal box, and carbon brushes not smaller than $\frac{1}{4}$ in. x $\frac{5}{8}$ in. (one on each side) on the contact surface should be used. If the machine be used as a dynamo (it will maintain five or six 110-volt lamps) metal brushes of the same surface should be used to reduce the resistance of the brush contact.

The field coil consists of No. 28 single-cotton-covered wire, wound to a depth of $\frac{3}{4}$ in. After the magnet is fitted as described in the beginning of the chapter, it is taken apart and two circular magnet heads of fiber $\frac{1}{8}$ in. thick and $3\frac{3}{4}$ ins. outer diameter are put on with a driving fit, care being taken that the distance along the core from outside to outside of the heads corresponds with the distance between the pole-pieces (5 ins.), when the whole is assembled. A groove must be cut on the inner face of one head from the center to the outer edge, in order to lead out the starting end of the field wire, and this must be covered with two layers of oil paper to prevent short-circuiting the successive layers of the coil. The core must be insulated with three layers of shellac muslin between the heads, and the field wire put on evenly, care being taken not to "spread" the heads. The exact number of turns is not a vital matter, but it should be as great as practicable so as to keep down the heat loss.

After winding the coil and securing the ends one pole-piece is put on solid and the other one slipped on until it begins to bind, when the journal yokes must be inserted between their arms, and the bolts put in as far as possible without jamming. Then by tightening up the journal-yoke bolts and the pole-piece bolt together, being particular never to draw the yoke bolt hard against the arm, the frame will come together in its original position. As an additional precaution it may be set on a true plane surface, and if the base of the loose pole-piece gets out of alignment tap the horn lightly until the frame is true on the bottom. The magnet frame must be provided with a non-magnetic base; hardwood is as good as anything,

the frame being secured by flat-head brass machine screws from below, two in each casting, countersunk in the wood.

The principal data for the machine are as follows:

TERMINAL E. M. F., 110 VOLTS

Armature current, normal	2 amps
Commercial efficiency (windage and friction losses estimated)	60%
Revolutions per minute	2,000

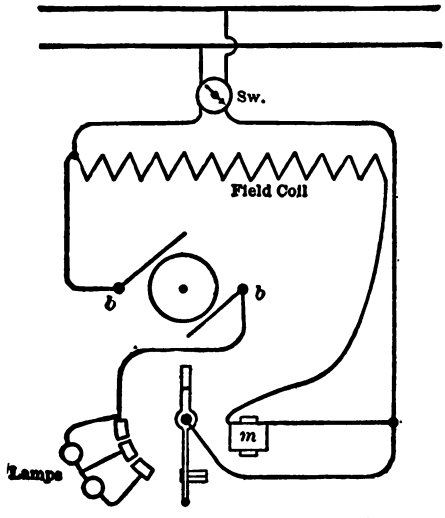

FIG. 26

It is advisable to provide a starting switch similar to the one shown diagrammatically by Fig. 26, where *b b* are the brushes; *S* the starting switch lever; *m* a magnet, and *Sw* a double-pole snap switch. The lamps shown are 50-volt, 32 candle-power lamps. The handle of the starting switch is provided with a spring tending to keep it in the position shown by the sketch. This starting switch is also suitable for use with the motor described in Chapter III.

CHAPTER V

ONE-HALF HORSE-POWER MOTOR WITH DRUM ARMATURE

FOR this size of motor three types of field magnet are described: the single-coil, like those previously described, a bipolar one-piece magnet of

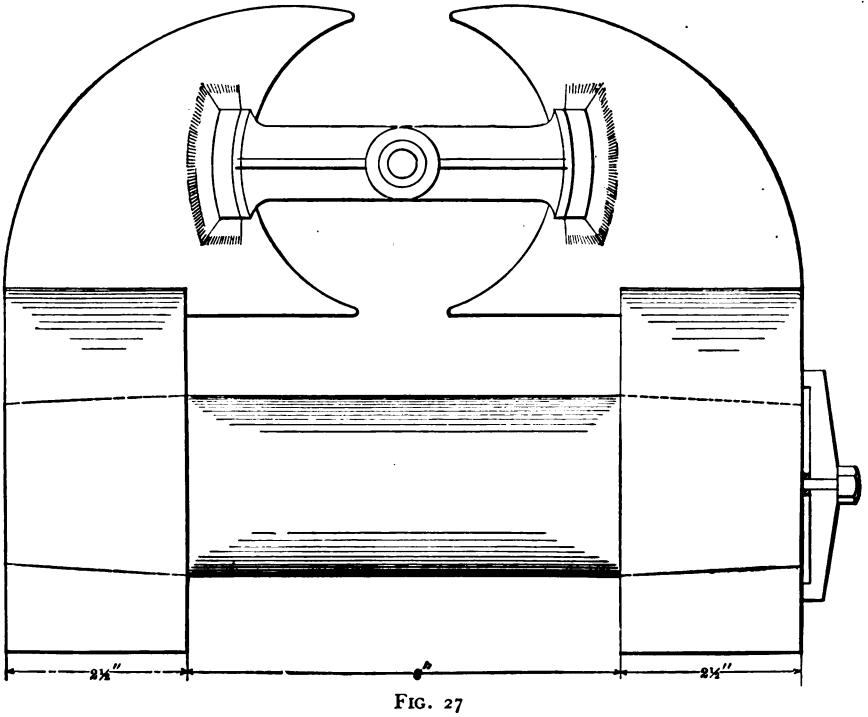

FIG. 27

the Lahmeyer type, and a similar form with four poles (Kapp type). The armature core and shaft are the same in each case, excepting the number

of slots in the armature of the four-pole machine. The machine is a ½ horse-power motor to operate on a 110-volt constant potential circuit at a speed of 2,000 revolutions per minute. The single-coil magnet (Figs. 27 and 28) has a round core of commercial wrought iron 2¾ ins. in diameter and 11 ins. long over all. The ends are turned tapering, as indicated by the dotted lines, to insure intimate contact with the yokes;

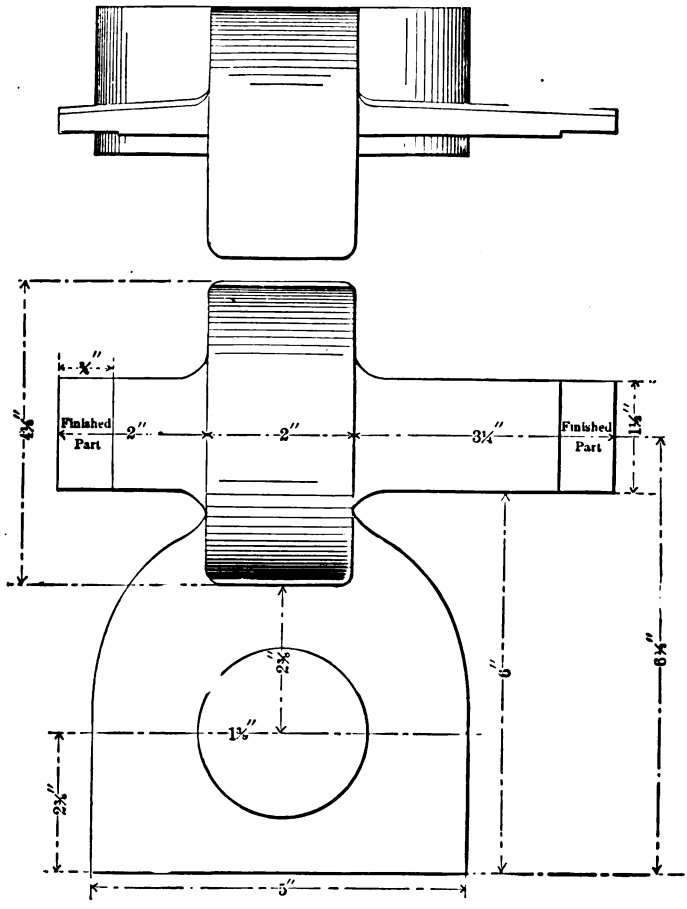

FIG. 28

the taper is from the full diameter to 2¼ ins., and begins 2½ ins. from each end. The pole-pieces are of cast iron. The arms which support the journal yokes are cast solid with the pole-pieces, and their horizontal thickness tapers from ½ in. at the pole-piece to ¼ in. where the yoke is bolted in place.

In fitting the magnet frame together the best procedure is to bore the tapered holes in the lower part of each pole-piece and turn the ends at the magnet core to the same taper, but just a trifle larger; then dress each tapered end of the core down very gradually with a fine file (the core being run on a lathe) until the pole-piece can be pushed on by hand far enough to bring the end of the core within 3-64 in. of the surface of the cast iron. The pole-pieces and ends of the core should be punch-marked so as to insure finally mounting each pole-piece on the end which was fitted to it. After dressing down the ends of the core as above described drill and tap in each end a hole for a $\frac{1}{4}$-in. machine screw, the purpose of which will be made apparent by a glance at the right-hand end of the complete magnet in Fig. 27, where *C* is a four-armed claw or spider, with a hole through the center where the arms intersect. The arms are $\frac{1}{4}$ in. thick, measured at right angles to the bolt, and taper from 3-16 to $\frac{3}{8}$ in. thick, measured parallel with it. One of these claws or spiders is used at each end of the core, though the drawing shows it at one end only.

After drawing one pole-piece home solid by means of the spider and bolt, slip the other on the other end of the core loosely and clamp the pole-pieces lightly between two iron plates with planed surfaces, applied between the journal arms, so as to keep the four horns of the pole-pieces in alignment; then force the second pole-piece home and clamp the horns hard between the iron plates. The bottom surface of the pole-pieces are then to be turned up on a shaper or planer and the iron clamping plates removed from the horns.

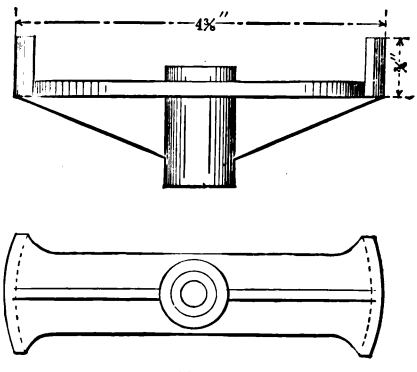

FIG. 29

The next operation is boring the armature chamber and the seats for the ends of the journal yokes. The bore of the armature chamber is 4 3-16 ins.; the seats for the journal yokes are machined to a $4\frac{5}{8}$-in. circle for $\frac{3}{4}$ in. from the outer ends. These operations must be completed before the original position of the frame on the lathe or boring machine is altered. This completes the machine work on the magnet, with the exception of the holes through the ends of the supporting arms and holes in the bottom surfaces of the pole-pieces for bolting to the base.

The journal yoke must be made of brass or some similar composition. The bar is 3-16 in. thick and $1\frac{1}{4}$ ins. wide, except near the ends, where it flares to correspond with the width of the supporting arms. At each end

is a right-angle lug, 3-16 in. thick after machining; these lugs fit the machined seats in the ends of the iron arms, and the yokes should be fitted to these arms before the frame is taken apart to put on the magnet coil. The journal box is 2 ins. long over all, $\frac{3}{8}$ in. of its length projecting on the inside of the yoke bar, and 1 7-16 ins. on the outside. As shown by the plan view of the yoke in Fig. 29, there are stiffening ribs starting flush near the ends of the yoke and attaining a height of $\frac{3}{4}$ in., where they join the box; these ribs are 3-16 in. thick. The box is $1\frac{1}{8}$ ins. in outside diameter and bored out $\frac{7}{8}$ in.; the bore is bushed to $\frac{5}{8}$ in. No particular form of oiling device is specified, as any amateur of sufficient ability to build such a motor will be fully competent to decide this detail for himself. The journal yokes are held in place by $\frac{1}{4}$-in. cap-screws passing through the ends of the supporting arms and tapping into the lugs on the yokes.

The field coil consists of No. 26 single-cotton-covered magnet wire, wound to a depth of 1 in. After the magnet is fitted as described it is taken apart and two circular fiber heads $4\frac{1}{2}$ ins. in diameter and $\frac{1}{8}$ in. thick are put on the core with a driving fit, care being taken that the distance from outside to outside of the heads corresponds with the space between the perpendicular faces of the pole-pieces when the frame is assembled; this measurement should be taken prior to dismantling the frame. A groove must be cut on the outer face of one head, from the center to the outer edge, in order to form a channel for leading out the starting ends of the coil when the frame is reassembled, at which time two discs of oil paper with one of mica between them must be threaded on the core outside of this head to insulate the leading-out wire from the pole-piece. Before winding the coil insulate the core with a strip of muslin just wide enough to go between the heads, and long enough to wrap around the core three times; this should be heavily shellacked before it goes on. The coil must be carefully wound so as to get in as many turns as possible without jamming the insulation, in order to keep down the heat loss.

After winding the coil and securing the ends, put one pole-piece on solid and slip the other on loosely. When it begins to bind bolt the journal yoke to the lugs on the pole-piece first put on, and insert the bolts through the lugs of the one that is loose. Then tighten up the spider bolt at the end of the core and force it into place, the bolts through the lugs serving as guides to keep the pole-piece from twisting on the core. These bolts should be set up little by little with the spider bolt, so as to keep the bolt heads within 1-16 in. of the surface of the lugs. As an additional precaution the frame may be set on a true surface and tried at intervals to see if it gets out of alignment; if it does, tap the horn of the loose pole-piece until the bottom surface agrees with the guide. The magnet frame

must be provided with a non-magnetic base, preferably composition metal, but allowably of wood.

Figs. 30, 31, and 32 show an armature disc, the shaft and armature core (the latter in cross-section), and the shell and head. The discs are of charcoal iron, 4 ins. outside diameter, with a 1-in. hole in the center and a $\frac{1}{8}$-in. key-seat, annealed after punching and key-seating; there are 18 slots 3-16 in. wide and $\frac{1}{2}$ in. deep. The shell and one head are cast in one piece (of brass), and consist of a barrel 1 in. outside diameter (when finished), and 2 ins. long, with a head, *s*, at one end, $3\frac{1}{8}$ ins. in diameter and tapered in thickness from $\frac{1}{4}$ in. near the center to 1-16 in. at the periphery; at the opposite end of the barrel is a cross-bar $\frac{1}{8}$ in. thick, cast with the barrel and of the shape shown, being $\frac{3}{8}$ in. wide where it joins the barrel and $\frac{3}{4}$ in. at the center. A $\frac{1}{2}$-in. hole is drilled in the center of this cross-bar and another in the center of the head, *s*, at the other end of

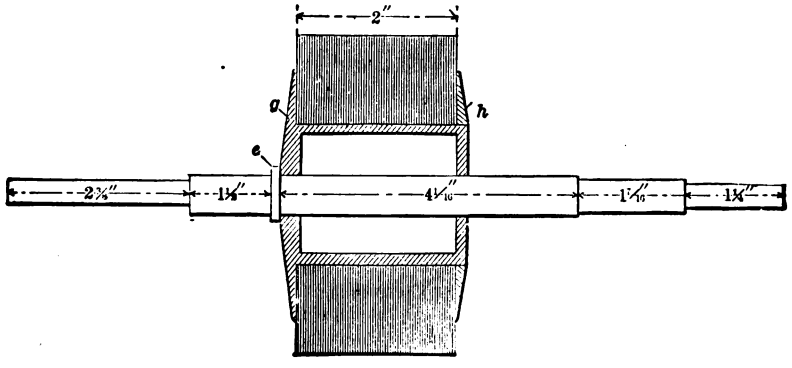

FIG. 31

the barrel; the shell is mounted on a mandrel, the barrel is turned down to fit the hole in the armature discs, and both sides of the head are faced off smooth. A $\frac{1}{8}$-in. key-seat 3-16 in. deep is cut in the barrel, so as to come in the center of one end of the cross-bar, as shown; a $\frac{1}{8}$-in. x $\frac{1}{4}$-in. feather, or parallel key, is laid in the key-seat, and the discs are threaded on the barrel and compressed against the head by the collar, *h*, drawn down by two bolts (not shown) passing through the collar and inside the barrel, and tapping into the head at the other end. This collar, *h*, is of brass, $3\frac{1}{8}$ ins. in diameter and tapering from 3-16 to 1-16 in. in thickness when finished. The opening in the center should fit the outline of the cross-bar on the end of the barrel at least closely enough to prevent the collar from shifting under stress of centrifugal force; the collar must be finished up smooth on both sides. A disc of insulation should be put on

next to the brass head before the iron discs are put on, and another insulating disc should go between the last iron disc and the clamping collar, *h*.

If the slots are cut in the core with a milling machine the discs must all come off the barrel to have the burrs removed, and also be reannealed; the key-seat will insure their returning in the original angular position. It is much better to have discs with the slots punched before the first annealing. The shaft is 11¾ ins. long over all; 1 in. in diameter in the largest part; ⅞ in. where the commutator goes, and ⅝ in. in the journals. A 1-16-in. x ⅛-in. collar, *e*, is shown back of the armature, the purpose of which is merely to "locate" the armature shell; it is not absolutely necessary, however, and may be left off if desired. The easiest way to provide for it is to make the shaft of 1¼-in. stock, leaving the original metal to form the collar when turning the shell to the proper diameter. The armature shell may be keyed to the shaft or pinned obliquely through the

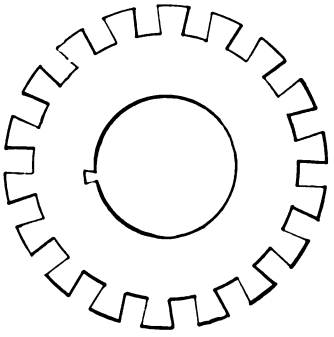

FIG. 30

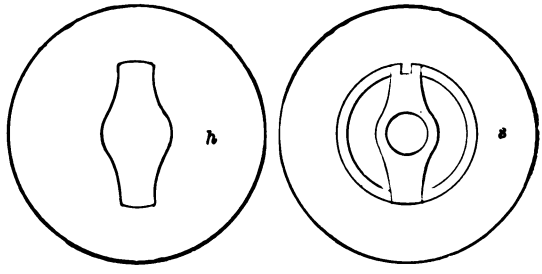

FIG. 32

thick part of the head; it must be positively secured by some such means.

The commutator shell must be bored to fit the ⅞-in. portion of the shaft, and must not exceed 1¼ ins. along the shaft. The lugs where the wires are attached to the segments may project toward the armature ⅛ in. or so. There must be 36 segments, and a diameter of 2½ ins. is recommended. The quadrant carrying the brush holders should be fitted to the inner end of the journal box, and carbon brushes (one on each side) not smaller than ¼ in. x ½ in. on the contact surface should be used. If the machine be used as a dynamo (it will maintain about ten 110-volt lamps) metal gauze brushes of the same surface may be used to reduce the resistance of the brush contact, but it is not strictly necessary. The armature winding is divided into 36 coils, each having 16 turns of No. 20 double-cotton-covered wire, 4 turns wide and 4 turns deep in the slot. The slots must be insulated with troughs of muslin and mica, or preferably

flexible micanite, 0.03 in. thick. The troughs are easily made by cutting the material into strips 2½ ins. long by 1¼ ins. wide, and slitting the ends so as to permit the projecting portion of the trough to be folded back flat against the core. Before putting in the troughs a disc of heavy drilling 3 ins. in diameter should be secured to each end of the core by means of varnish, and the outer faces varnished and allowed to nearly dry. Then put in the troughs and put on two more muslin discs, varnishing the whole, and bake until thoroughly dry. Instead of winding each coil in diametrically opposite slots, take slots lacking one of being precisely opposite.

A good plan is to make a sketch of an armature disc and number the slots from left to right successively around the periphery. Then wind the coils as follows, the coil numbers indicating the order in which the coils are put on, not the order in which they are connected to the commutator:

COIL NO. —	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
COIL NO. —	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

STARTS IN SLOT NO. —	1	10	13	4	7	16	2	11	15	6	14	5	18	9	3	12	8	17
ENDS IN SLOT NO. —	9	18	3	12	15	6	10	1	5	14	4	13	8	17	11	2	16	7

Each pair of coils must be covered with muslin where they cross the heads before the next pair is put on, and before coil No. 8 is wound on top of coil No. 1 in slot No. 1 the bottom coil must be insulated by a strip of micanite laid in the slot; this is true of every bottom coil.

After the winding is on, and before connecting up to the commutator, the band wires should be put on. Use No. 19 B. W. G. soft tinned-iron wire, known by hardware dealers as "white stove-pipe wire," for the bands, and put them on under as heavy pressure as possible without endangering the armature shaft. Two bands of eight turns each, ½ in. from each end of core, will suffice. A strip of mica between two strips of fullerboard must go under each band, and the bands should be soldered at intervals, not all the way around. Four tin clips located equidistantly, with a dab of solder at each, will give ample security.

If cast steel be available, one of the iron-clad types of magnet, shown by Figs. 33 and 34, is somewhat preferable because of the small amount of machine work required. Of these two the four-polar type is considered preferable by the writer, being much lighter in weight, and having an "open-head" armature winding. Each of the iron-clad magnets is a single casting; the essential dimensions are shown in the sketches, with the exception of the bore of the armature chamber, which is, of course, the same as for the single-coil magnet — 4 3-16 ins. As the two magnets require the same treatment, varying only in dimensions, the following remarks apply to both:

It will be noticed that the feet of the machine project ⅛ in. below the

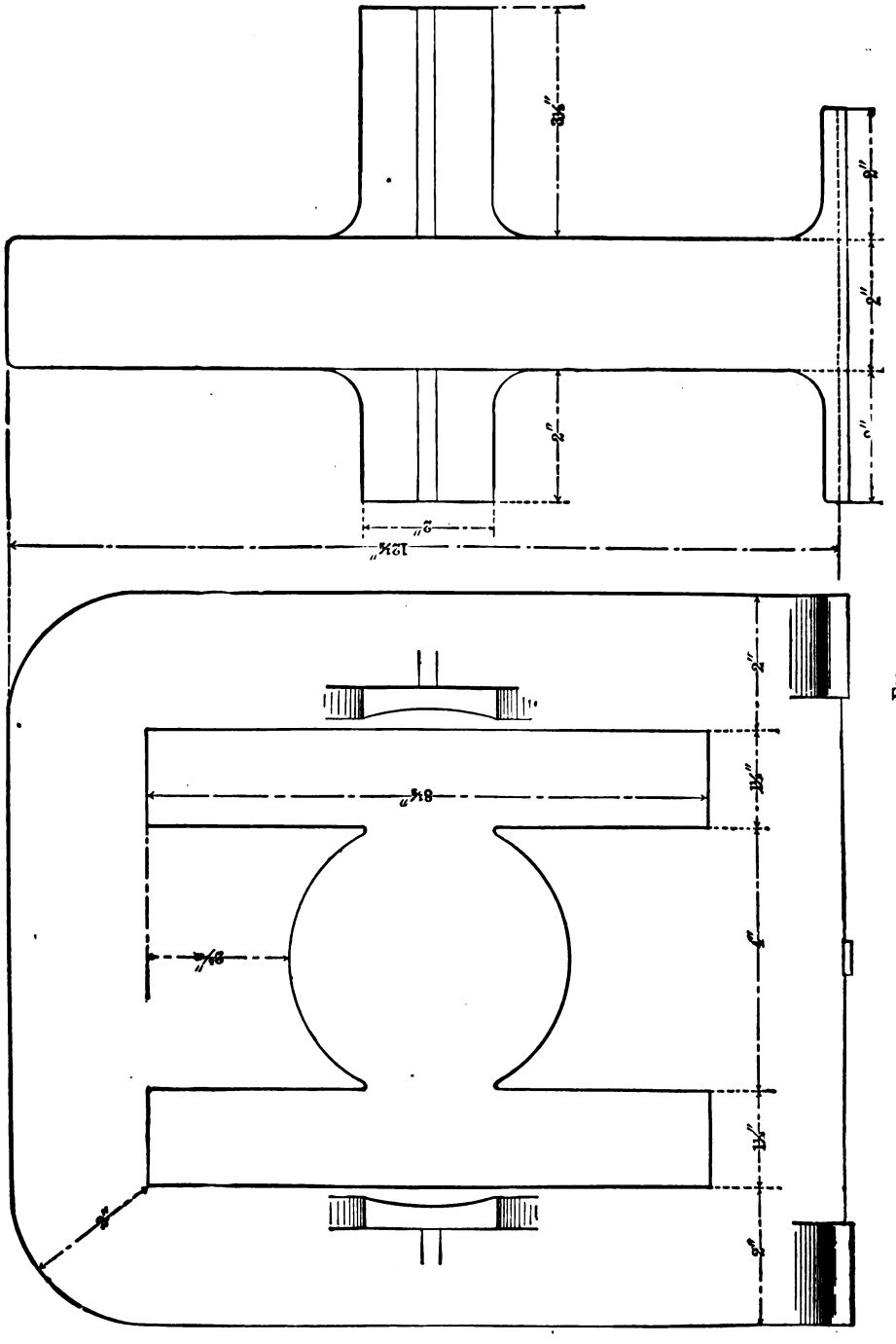

FIG. 33

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body and that there is a transverse rib under the center of similar depth. These are to give the machine a floor bearing which may be trued up on a shaper or planer without finishing the whole bottom of the machine. The first operation on the casting is chipping off the numerous fins and lumps with which steel castings are invariably afflicted. An emery wheel may be used for this purpose around the outside of the frame, but in the corners of the coil spaces a cape chisel and lots of muscular exertion will be required.

Next, the bearing surfaces are trued up, and $\frac{1}{2}$-in. holes drilled in the feet; then the magnet is mounted for boring out the armature chamber and the seats for the journal yokes, all of which must be done with one mounting. This finishes the magnet frame, unless it is desired to put a terminal block on the machine instead of on the base and do away with

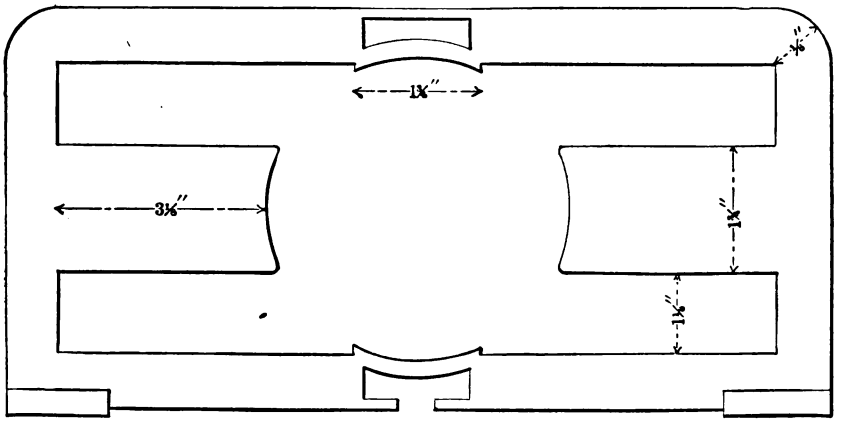


FIG. 34

the latter. In this event four $\frac{1}{4}$-in. holes are to be drilled in the top surface of the frame and tapped for machine screws to hold the block, which may be 2 by 6 ins. and $1\frac{1}{2}$ ins. thick. The journal yoke and journal are the same as shown in Fig. 29, except that for the bipolar magnet the yoke is $7\frac{1}{2}$ ins. long instead of $4\frac{5}{8}$ ins.

The field coils for the bipolar machine consist of No. 25 single-cotton-covered wire wound $1\frac{1}{4}$ ins. deep, and each coil is 2 ins. long parallel to the magnet core. The coils should be wound in fiber bobbins, as shown by Fig. 35. The heads of the bobbin must be 2 ins. apart, and the body must be $\frac{1}{8}$ in. wider and longer than the magnet core, actual measurement. Before winding the coil the bobbin must be mounted on a wooden core of proper size to fit the opening through the center, and having flanges or heads at each end to "back up" the heads of the bobbins; one of these

heads is put on permanently and the other is secured by two screws so as to be removable. A spindle of 1-in. iron goes through the center of the wooden core upon which to mount it in the lathe for winding.

When a coil is completed bend the wire back upon itself near the end, tie a linen thread in the loop formed, and secure the end of the coil by passing the thread several times around the coil and tying its ends together. Then varnish the outside heavily and bake the coil at a low temperature — 100 to 125 deg. Fah. — until the varnish is hard.

The coils for the four-polar machine are 1 in. deep and 3 ins. long, of No. 25 single-cotton-covered wire. The heads of the winding bobbin are 3 ins. apart. The instructions for winding the coils for the bipolar iron-clad machine apply to these also. In connecting the coils on the machine, however, there is a difference. On the bipolar machine the final end of one coil must be connected to the beginning of the other; on the quadripolar the reverse is true. Fig. 37 shows diagrammatically the

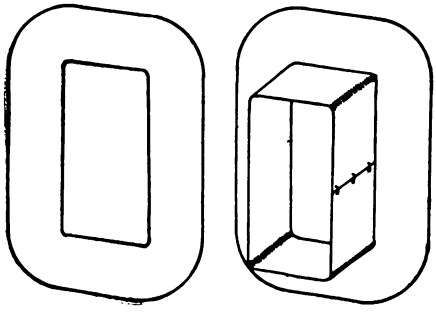


FIG. 35

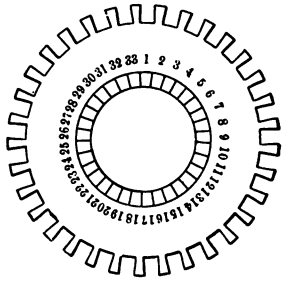


FIG. 36

manner of connecting the field coils of the quadripolar machine. It will be noticed that the exciting current passes around the cores in opposite directions. The connection for the bipolar machine is exactly the reverse of that shown.

The armature core of the four-pole machine has 33 slots 0.2 in. wide and $\frac{1}{2}$ in. deep. There are 33 coils, each having 20 turns of No. 20 wire, 4 turns wide and 5 turns deep. These may be wound directly on the core, but it will probably be easier for an amateur to wind them in a little frame, tie them at intervals with thread and put them on the core complete. The winding frame will be exactly like the one for the field coils except in size. The "channel" formed between the heads must be $\frac{1}{8}$ in. wide and 7-32 in. deep. The body of the frame, which determines the length and width of the coil, is $2\frac{1}{4}$ ins. one way and $2\frac{3}{4}$ ins. the other. The coils are put on and connected up as indicated by the accompanying table.

TABLE OF WINDING AND CONNECTIONS

NUMBER OF COIL	IN SLOTS NOS.	BEGINNING END GOES TO SEGMENT NUMBER	FINAL END GOES TO SEGMENT NO.
1	1 and 9	1	17
2	2 " 10	2	18
3	3 " 11	3	19
4	4 " 12	4	20
5	5 " 13	5	21
6	6 " 14	6	22
7	7 " 15	7	23
8	8 " 16	8	24
9	17 " 25	17	33
10	18 " 26	18	1
11	19 " 27	19	2
12	20 " 28	20	3
13	21 " 29	21	4
14	22 " 30	22	5
15	23 " 31	23	6
16	24 " 32	24	7
17	25 " 33	25	8
18	26 " 1	26	9
19	27 " 2	27	10
20	28 " 3	28	11
21	29 " 4	29	12
22	30 " 5	30	13
23	31 " 6	31	14
24	32 " 7	32	15
25	33 " 8	33	16
26	9 " 17	9	25
27	10 " 18	10	26
28	11 " 19	11	27
29	12 " 20	12	28
30	13 " 21	13	29
31	14 " 22	14	30
32	15 " 23	15	31
33	16 " 24	16	32

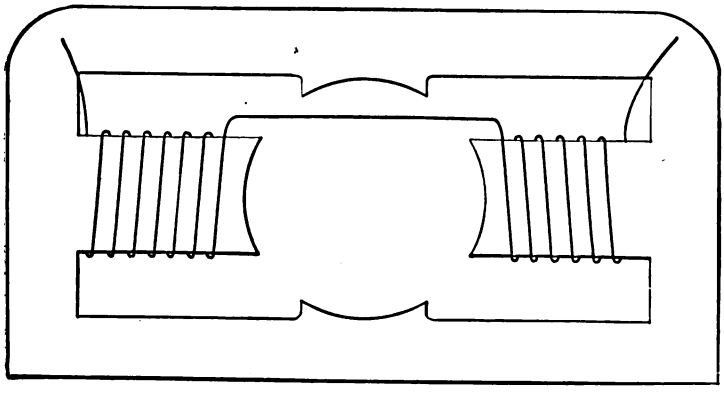


FIG. 37

The numbers of the coils indicate the sequence in which they are put on the core, and this order should be observed in order to secure maximum symmetry of the wires across the heads of the core. The numbers of the slots and segments refer to the diagram shown in Fig. 36. Each figure applies to the slot and segment between which it is located.

The brush quadrant for this machine is also different from that of the other two; instead of bearing upon the commutator at diametrically opposite points, the brushes must be 90 deg. apart — corresponding with the relative angular positions of magnet poles of different signs. In the bipolar iron-clad the "north" and "south" poles are, of course, opposite each other; in the four-pole machine the poles directly opposite are of the same sign — if one horizontal pole is "north" the other must also be "north," and the other two, without coils, will be "south."

CHAPTER VI

ONE HORSE-POWER BIPOLAR MOTOR WITH DRUM ARMATURE

THE accompanying drawings and description will enable any one with moderate machine-shop facilities to build a 1 horse-power motor to work on a 110-volt direct-current circuit. Two types of field magnet are given, the armature and shaft being the same in both cases.

The armature is 4 ins. in diameter, outside, with twenty-four slots, each 7-32 in. wide and $\frac{5}{8}$ in. deep. Fig. 38 shows the shaft and a cross-sectional view of the armature core. The discs are compressed by two cast-iron end plates, which are screwed on the shaft; these plates are $\frac{1}{2}$ in.

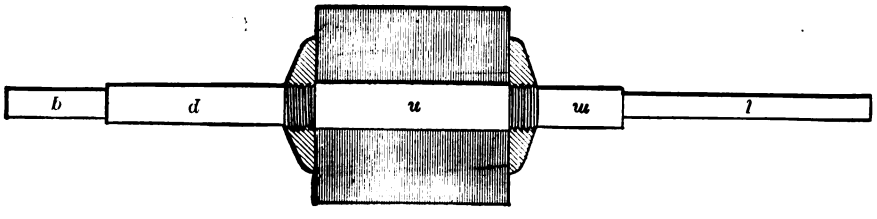


FIG. 38

thick at the shaft, and taper to 3-16 in. thick at the outer edge, which is rounded as shown, to avoid abrading the insulation between the core and the windings. The full list of armature dimensions is as follows:

	Core			Shaft			
	Body.	Heads.	at l.	m.	n.	p.	q.
Diameter	4	$2\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$
Axial length	4	$\frac{1}{2}$	5	$1\frac{3}{4}$	5	$3\frac{3}{4}$	2

The discs should have a shallow key-seat in the edge of the central hole, and the shaft should be correspondingly key-seated, and a spline, or perfectly straight key, $\frac{1}{4}$ in. square, should be used to transmit the movement of the discs to the shaft. If this is done, the slots in the periphery

of the discs may be milled out; the armature core must be dismantled after the slots are cut, and the burr which is left by the milling center smoothed off. If the key and key-seats are properly fitted the discs will go back on the shaft in precisely the position in which the slots were cut, and the sides of the latter will be smooth. If the key is a loose fit, however, it will be advisable to use a straight-edge in one of the slots to insure perfect accuracy in reassembling the discs. It is scarcely necessary to urge a very careful and close fit of the key and its seats. In assembling the core, one of the cast-iron heads should, of course, be screwed to place first; then put on a disc of vulcanized fiber, 1-16 in. thick, 4 ins. in diameter, and next thread on the iron discs. After the last iron disc put on another fiber disc and follow with the end plate or head of cast iron, which will have to be set up with a pin wrench. If the discs are purchased with the slots already stamped out notches will have to be cut in the fiber end discs to correspond with the armature slots; if the slots are to be milled the fiber discs will, of course, be cut along with the iron ones. The latter

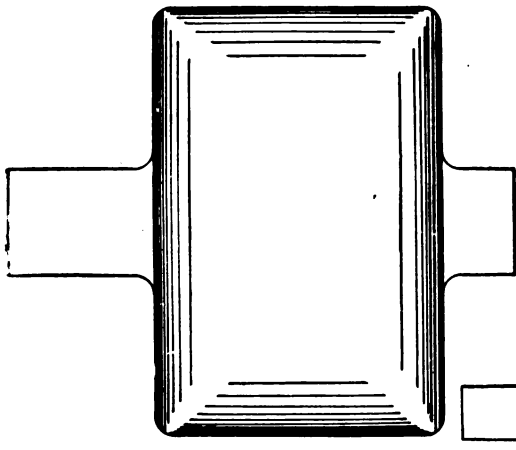


FIG. 39

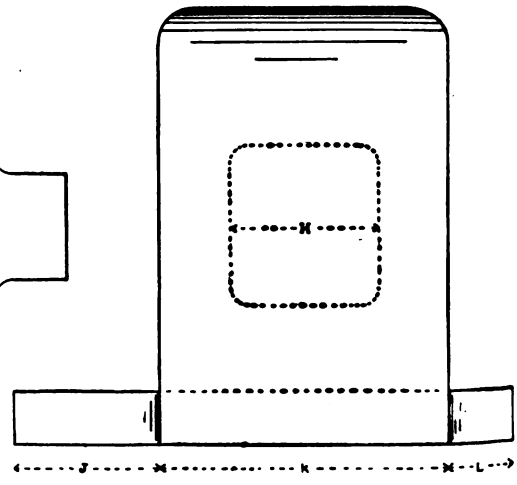


FIG. 40

must be not over 25 mils thick and preferably thinner; care should be taken to get low-carbon annealed steel discs.

Of the two types of field magnets shown, the iron-clad is preferable from a constructional standpoint, as the only operations are boring out the armature chamber and the seats for the journal pedestals, and drilling the bolt holes for the latter. Fig. 39 gives a plan view of the iron-clad magnet, Fig. 40 an end view and Fig. 41 a side elevation. The thickness of the magnet core (the portion on which the coils are placed) parallel

with the shaft is $4\frac{1}{4}$ ins. except right at the pole face, where it is rounded down to 4 ins.; this is necessary in order to reduce the flow of magnetism from the pole to the cast-iron end plates of the armature, which produces waste of energy by heating. The complete measurements of the field magnet are as follows:

	INCHES
A — Thickness of yoke portion of magnet	$1\frac{1}{2}$
B — Inside length of horizontal part of yoke	8
C — Vertical thickness of magnet core	$4\frac{1}{2}$
D — Distance from core to yoke	$2\frac{3}{8}$
E — Total outside width of magnet frame	11
F — Width of journal foot	3
G — Radius to which journal seat is bored	$4\frac{7}{8}$
H — Horizontal thickness of magnet core (see above)	$4\frac{1}{4}$
J — Length of journal foot, commutator side	$4\frac{3}{8}$
K — Width of magnet yoke or frame, axially	$8\frac{1}{4}$
L — Length of journal foot, pulley side	$2\frac{3}{8}$

The bore of the pole-pieces is 4 3-16 in. in diameter, and this figure must be rigidly observed for best results, as all the calculations are based upon the resulting length of air-gap. The above dimensions are intended to apply to a magnet made of the best grade of cast iron; Scotch pig should be used if it is obtainable, and if not, then the very best grade of soft iron. The casting should be allowed to remain in the mold until it is absolutely cold, care being taken not to remove any of the sand from about the magnet proper. The sand can be scraped away from the extreme end of the longer of the two pedestal feet, so as to enable the molder to ascertain when the casting is cold. It is frequently the case that a casting requires as much as two days to thoroughly cool, but it should not be disturbed before it is cold.

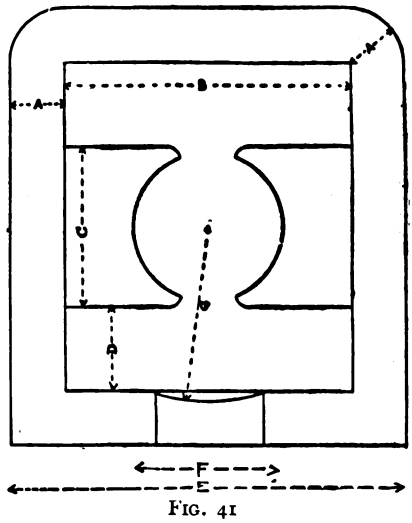


FIG. 41

Fig. 42 gives outside and cross-sectional views of the journal pedestal for this magnet; the two pedestals are alike in every particular, and when in position on the projecting feet of the field-magnet frame their outer edges should be exactly flush with the ends of the feet. The pedestals are of iron; the base is curved to conform to the arc of the circle to which the upper surface of the foot is machined, and is $\frac{3}{8}$ in. thick. The standard consists of two ribs at right angles with each other, each $\frac{3}{8}$ in. thick, with

their edges curved as shown. The box is of the ring-oiling type, with a single ring hung midway of the journal; the bushing is easily made from thin brass tubing, $\frac{3}{4}$ in. outside diameter, and with a very thin wall (not over 1-32 in.), babbitted to fit the shaft and having a slot $\frac{3}{8}$ in. wide cut half way through it, midway between its ends. This bushing is shown in Fig. 43, which represents the bearing for the other type of magnet, to be presently described. The bushing is $1\frac{3}{4}$ ins. long; the oil ring is made of brass, one inch in diameter inside, $1\frac{1}{8}$ ins. diameter outside, and $\frac{1}{4}$ in. wide along the shaft. Reference to the side views of the journal pedestal will show a slot in the upper wall of the box portion, through which the

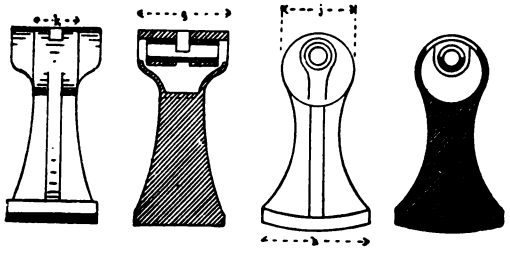


FIG. 42

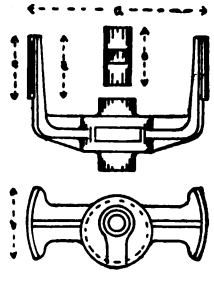


FIG. 43

oil ring is inserted before putting in the bushing. A cover should be provided for this slot to keep out dust, etc. The dimensions of the journal pedestals are as follows:

	INCHES
g — Length of base and journal box	$2\frac{1}{4}$
h — Width of base	3
j — Outer diameter of reservoir	2
k — Axial length of reservoir, outside	$1\frac{1}{4}$
Internal diameter of reservoir	$2\frac{3}{4}$
Internal length of reservoir	1

The bore of the box portion of the pedestal must, of course, be made to fit snugly the outer diameter of the tubing used for a bushing, as the wall of the latter is too thin to admit of turning it down to fit a predetermined bore in the pedestal. After boring the pedestal to fit the bushing it should be mounted on a mandrel and its base turned to fit the circle of the foot on the magnet frame, namely, $9\frac{3}{4}$ ins. in diameter. Each pedestal should be fastened to the foot with two $\frac{1}{4}$-in. cap screws.

Fig. 44 gives a side elevation of a much lighter magnet, which may be used in connection with the armature above described, if the builder has sufficient skill and facilities to do the machine work accurately. The magnet core is a round piece of wrought iron, $3\frac{1}{4}$ ins. in diameter, with its

ends turned down to $3\frac{1}{8}$ ins. diameter for a distance of 4 ins. from each end; the total length of the core is $12\frac{1}{4}$ ins., so that the length of the untouched portion will be $4\frac{1}{4}$ ins. The pole-pieces are of cast iron, only the very best possible grade being suitable. Where the core enters the cast iron the latter is 4 ins. square, with the corners rounded, and having two ribs or flanges, *f*, *f*, running along one edge; these continue clear up to the top of the pole-piece, and are 1 in. thick by 2 ins. wide. Fig. 45 shows an end view of the magnet frame, and Fig. 46 a plan view. The hole occupied by the wrought-iron core should be cored out to $2\frac{7}{8}$ ins. diameter when the casting is made, and afterward bored to a driving fit of the end of the core.

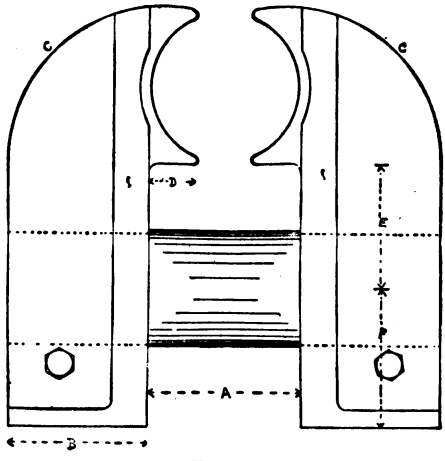


FIG. 44

The first operation should be turning off the ends of the core; next, bore the holes in the pole-pieces (or, more strictly speaking, the yokes).

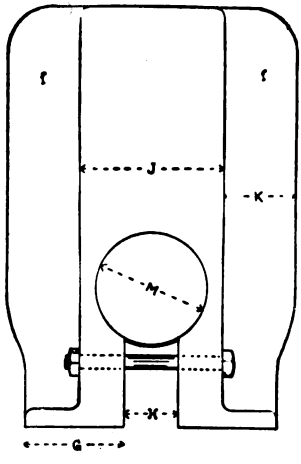


FIG. 45

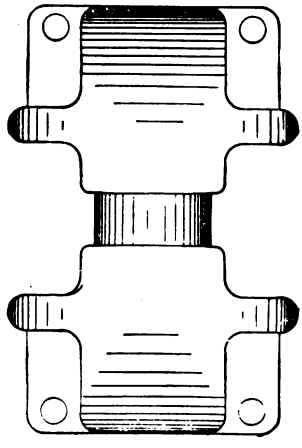


FIG. 46

Then drill a $\frac{3}{8}$-in. hole through the yoke just below the lower edge of the big hole and at right angles with it, to accommodate the clamping bolt shown in Fig. 45. Next drive one end of the core into one yoke and set

up the nut on the end of the clamping bolt; then put on the other yoke and twist it on the core until the four horns of the pole-pieces are exactly opposite each other, tighten up the second clamping bolt, and plane off the bottom surfaces of both yokes. To bring the pole horns into alignment, the simplest method is to cut out two heavy blocks of hard wood, say 3 ins. thick and $3\frac{1}{2}$ ins. square; bore a $\frac{1}{2}$-in. hole through the center of each block, run a $\frac{1}{2}$-in. bolt, 12 ins. long, through the two blocks, and apply them to each side of the pole-pieces, the bolt passing through the armature chamber in about the position to be occupied by the shaft. Set up the nut on the bolt until the blocks are hard against all four pole horns, and then tighten up the clamping bolt in the foot of the loose yoke.

After planing off the feet of the frame, bore out the armature chamber 4 3-16 ins. in diameter, and the seats for the journal yokes (in opposite faces of the side flanges, *f*, *f*), 5 ins. in diameter, and then remove one magnet yoke and put on the magnet coil. If the coil is separately wound in a form (which is preferable) only one yoke need come off; if it is wound directly upon the core, both yokes must come off, of course. The base of the machine must be of wood or brass. Wood is better, as, aside from its cheapness, it affords convenient space for the terminal posts and fuse-block of the machine. The base should be 15 ins. x 18 ins., made of two pieces of hard wood each $1\frac{1}{2}$ ins. thick, glued and screwed together with the grains at right angles. The longer dimension of the base is to go parallel with the shaft, and the machine should be so set as to allow the pulley to overhang the edge of the base-board.

The pulley should be 4 ins. in diameter and 2 ins. wide on the face; the latter should be crowned. The pulley should preferably be keyed to the shaft, with a set-screw in the pulley hub on top of the key. If only a set-screw be used to hold the pulley on the shaft, a "flat" must be filed on one side of the shaft under the point of the set-screw.

The journal box and yoke for this magnet is shown by Fig. 43. It must be made of brass or some other non-magnetic composition. The design and dimensions of the oil reservoir, journal box, and bushing are exactly the same as those given for the journal box of the iron-clad magnet above. All the dimensions are given in the following list, along with those of the magnet just described.

	INCHES
A — Distance between yokes	$4\frac{1}{4}$
B — Thickness of yoke	4
C — Radius of outer curve of pole-piece	$4\frac{1}{4}$
D — Length of pole horn	$1\frac{3}{8}$
E — Distance from pole horn to center of magnet core	$3\frac{1}{4}$
F — Distance from floor line to center of magnet core	$3\frac{1}{4}$
G — Width of foot	$2\frac{3}{4}$
H — Width of slot under core hole in yoke	$1\frac{1}{2}$
J — Width of yoke	4

K	— Width of flange	2
a	— Diameter of curve of journal yoke ends and seats	5
b	— Vertical width of journal yoke arms	$2\frac{1}{4}$
c	— Length of machined portion of yoke arms	$1\frac{3}{4}$
d	— Distance from end of yoke arm to inner end of journal box, pulley end of shaft	2
d	— Distance from end of yoke arm to inner end of journal box, commutator end of shaft	4
e	— Length of bushing	$1\frac{3}{4}$
g	— Length of journal box	$2\frac{1}{4}$
h	— Slot to let in the oil ring	$\frac{3}{8}$x$1\frac{1}{4}$
j	— Outer diameter of oil reservoir	2
	Outer length of reservoir, axially	$1\frac{1}{4}$

The armature core and field-magnet frames may be wound for any voltage desired, but the most efficient windings, as the cores now stand, will be those specified below.

ARMATURE WINDING

The armature core, after being finally assembled, is to be made ready for windings by applying the insulation. Cut out four discs of heavy canvas, 3 ins. in diameter, with a $\frac{3}{4}$-in. hole in the center; varnish two of them on one side with shellac varnish, and apply them to the end plates of the armature core, varnished sides in. The edges will turn over to cover the outer edges of the plates, and will have to be slitted at intervals of $\frac{1}{8}$ in. all around to prevent bunching up. After putting on these varnish their outer faces, and one face of each of the remaining canvas discs; when the varnish begins to thicken put on the two other discs, one at each end, and apply considerable pressure to them until they dry. This is best accomplished by boring a hole in a piece of plank, large enough to pass the shaft, and setting the core on the plank, on end, next putting a short piece of board (6 or 8 ins. square) with a hole in its center on the upper end of the armature, and piling any convenient pieces of heavy scrap on the top board.

Next insulate the slots with troughs of oil paper, 1-64 in. thick, such as is used with the ordinary office outfit for copying letters; each trough should consist of two thicknesses of the oil paper, and the floor of the trough should be $4\frac{1}{4}$ ins. long, so as to project a little beyond the iron of the core and rest upon the edges of the canvas discs, which were previously turned over to cover the edges of the end plates.

The coils may then be wound directly in the slots, each coil consisting of 20 turns of No. 18 double-cotton-covered wire, 4 wide and 5 deep. Each slot will contain, when the windings are complete, half of each of two separate coils. It will facilitate the winding and insure electrical balance (as nearly as a core-wound armature can be balanced) if the builder will make a diagram of his armature disc, numbering the slots

from 1 to 24 successively around the circumference, as shown by Fig. 47. Then the winding will proceed as follows:

First	coil	starts in slot No.	1,	ends in slot No.	12
2d	coil	starts in slot No.	13,	ends in slot No.	24
3d	coil	starts in slot No.	17,	ends in slot No.	4
4th	coil	starts in slot No.	5,	ends in slot No.	16
5th	coil	starts in slot No.	9,	ends in slot No.	20
6th	coil	starts in slot No.	21,	ends in slot No.	8
7th	coil	starts in slot No.	3,	ends in slot No.	14
8th	coil	starts in slot No.	15,	ends in slot No.	2
9th	coil	starts in slot No.	19,	ends in slot No.	6
10th	coil	starts in slot No.	7,	ends in slot No.	18
11th	coil	starts in slot No.	11,	ends in slot No.	22
12th	coil	starts in slot No.	23,	ends in slot No.	10
13th	coil	starts in slot No.	22,	ends in slot No.	11
14th	coil	starts in slot No.	10,	ends in slot No.	23
15th	coil	starts in slot No.	18,	ends in slot No.	7
16th	coil	starts in slot No.	6,	ends in slot No.	19
17th	coil	starts in slot No.	14,	ends in slot No.	3
18th	coil	starts in slot No.	2,	ends in slot No.	15
19th	coil	starts in slot No.	20,	ends in slot No.	9
20th	coil	starts in slot No.	8,	ends in slot No.	21
21st	coil	starts in slot No.	16,	ends in slot No.	5
22d	coil	starts in slot No.	4,	ends in slot No.	17
23d	coil	starts in slot No.	24,	ends in slot No.	13
24th	coil	starts in slot No.	12,	ends in slot No.	1

After winding the first two coils, thin strips of varnished muslin should be laid over them, across each armature head from slot to slot, so that the next two coils will be insulated from the first pair; each successive

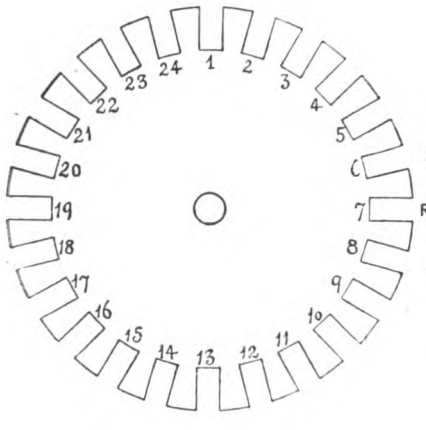


FIG. 47

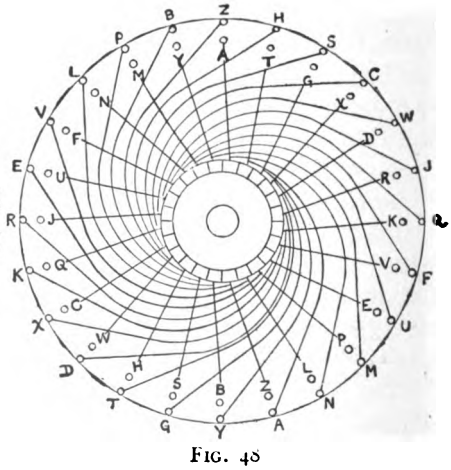


FIG. 48

pair of coils should receive this treatment, and after the slots are half filled (twelve coils being put on), a strip of oil paper 7-32 in. wide and

$4\frac{1}{4}$ ins. long must be laid in each slot on top of the coil already in place before proceeding to put on the coil which next goes in that slot.

The starting end of each coil should be kept leading out straight from its slot, and the finishing end should be brought across the head and secured to the starting end by a turn around it. When the winding is complete, untwist the finishing end of each coil from its starting end, and twist it and the starting end of the next coil to the right firmly together. This will leave twenty-four terminals to lead out to the commutator lugs.

Before connecting the ends to the commutator, the binding wires should be put on and the winding tested for grounds on the core. The binding wires are put on in two bands, and consist of small tinned-iron wire; they should be put on beginning 1 in. from each end of the core, and making each band $\frac{1}{2}$ in. wide. The binding wire should be wound on strips of thin varnished muslin laid around the core two layers deep, and the bands should be soldered at four equidistant points around the armature surface, not all the way around. The wire used should be not larger than No. 22 B. W. G. or No. 20 B. S. G.

Unless the machine is likely to be used in very dusty surroundings it is better not to put any covering over the ends of the armature after the winding is complete. If the instructions for insulating each pair of coils from the succeeding pair have been carefully followed out, any ordinary collection of dust will not be liable to cause a breakdown in the heads.

The commutator had better be purchased from any well-known manufacturer of commutators, as its market price will be less than the cost of material and labor necessary to make one properly. It must have twenty-four segments and be not more than 2 ins. long along the shaft; the diameter does not matter particularly — take one of a stock size from the maker. In connecting up the coils to the commutator carry the ends previously twisted together straight out to the commutator segments. Fig. 48 shows the connections diagrammatically. The slots are omitted and each coil is represented as having only one turn for the sake of simplicity. The coils are lettered, to facilitate identification of opposite ends. The ends leading straight to the commutator are the starting ends; those leading around being the final ends. The diagram is not intended to show the relative radial positions of the coils, and care must be observed to avoid becoming confused. For example, coil *A* may or may not be under coil *Z* at its starting side; they are both in the same slot, but it does not matter which is on top. If coil *A* was the first one put on, it will, of course, be in the bottom of both of its slots, and coil *Z* will come on top of each side of it. The diagram only shows the relative angular positions of the coils and the manner of connecting their ends. The brushes should be of carbon, $\frac{3}{8}$ in. thick, and of a width $\frac{1}{8}$ in. less than the length of the

commutator face, which should be about 1½ ins. The brush-holders may be copied from any standard type to which the builder of this motor has access.

The iron-clad magnet requires two magnet coils, one on each pole; for 110-volt circuits these coils consist of No. 22 single-cotton-covered wire wound 2⅛ ins. deep, each coil being 1½ ins. long. If both the coils are wound in the same direction — in other words, if they are precisely alike as to the manner of winding, as they should be — the beginning end of one must be connected to the final end of the other, the two remaining ends being carried to the terminals of the machine. The best arrangement is to connect the two ends that are farthest apart, making this connection on the pulley side of the machine. The coils should be wound on a block, the cross-section of which is of exactly the same shape as that of the magnet core at its largest part, but which measures ¼ in. more in each direction. After winding each coil, tie it at each corner with coarse linen thread (cobbler's thread) and cover it with strips of muslin wound at right angles to the direction of the wires, and so put on as to have the edge of each convolution of muslin lay just alongside that of its neighbor — touching it but not lapping it. The muslin must be one fourth the width of the inner edge of one side of the coil, so that four turns will cover one side evenly. Put the muslin on in two layers, the turns of the second layer covering the joint between the turns of the first layer. Then wind strips over the corners of the coils, two layers deep. After the coil is covered with one layer, varnish the muslin covering heavily with shellac; when this is nearly dry, put on the next layer and the corner strips, and after varnishing the whole set the coil aside to dry. Do not put any varnish on the wire itself. Next cover the iron cores of the machine with a layer of muslin, this time lapping the edges of successive convolutions; varnish the muslin, and when it and the coils are thoroughly dry, put the latter on. Unless the pattern for the field magnet has been very exactly made, and the casting is an unusually perfect one, it may be necessary to file the corners of the pole-pieces slightly to get the coil between them in putting on the magnet core. In filing these corners, be careful to round them, leaving no sharp corners or edges whatever. It is advisable to do this, even if it is not mechanically necessary for the introduction of the coils.

The single-core magnet has only one magnet coil, of course. This consists of No. 25 single-cotton-covered wire, wound to a depth of 1¼ ins. and a length of 4 ins. Circular magnet heads of vulcanized fiber should be used to protect the ends of the coil, as the full voltage of the machine exists between these ends; these heads should be ⅛ in. thick and 6⅜ ins. in diameter, with a hole to fit the magnet core snugly if the coil is wound directly on the core. If not, a bobbin should be made, the center consisting

of a tube of 1-32-in. fiber, 4¼ ins. long, and of an internal diameter to go easily over the core; the heads of the bobbin to be of ⅛-in. fiber, as above. If the coil is wound on the core, the latter must be covered with two layers of muslin, each layer varnished with shellac. The whole must dry thoroughly before the wire is wound on.

The data of the machines are as follows:

Terminal e. m. f.	110 volts
Armature capacity, maximum	8.3 amp.
Armature capacity, normal	7 amp.
Magnetic flux per sq. in. in armature core	71,800
Revolutions per minute, loaded	1,800
Efficiency, approximately	70%

An amateur motor builder will be wise not to attempt to make a starting box for this size of machine; one can be purchased for a moderate sum from any of half a dozen reputable manufacturers, and, as either of the motors here described is well worth the outlay necessary to insure its protection in this particular, the writer advises buying the starting rheostat.

If, however, the reader particularly desires to make his own starting rheostat, the arrangement shown by Fig. 49 will be found easier to construct than anything in the shape of a wire rheostat. In the sketch, *L* is the lever, pivoted on a ½-in. metal post, and normally forced downwardly by a coil spring of three or four turns (not shown), which is located under the washer, *W*. A pin through the post secures the washer, spring, and lever. *H* is the handle; a wooden handle, such as coffee grinders are given, or a large porcelain knob, will answer. *B* is the contact brush of copper, slitted tangentially to the circles of the contact strips, *c*, *c*, *c*, *c*, *c*, *c*, *c*; these circles have their common center, of course, in the center of the post on which *L* is pivoted. An end view of the brush, *B*, is given by *E*, showing the convex shape given the under face of the brush to enable it to pass smoothly over the contact strips. The end of these should be beveled to avoid digging into the brush.

The connections are shown diagrammatically. *R* is a bank of five 32 candle-power incandescent lamps, rated at 110 volts (100 will be better, and they can probably be readily obtained); *C* is the motor commutator; *b*, *b*, the brushes; *F*, the field winding; *S*, a double-pole combined switch and fuse block, and *M* the service mains. A glance at the connections will show that the functions of the lever *L* are to first connect in the field, next the armature in series with one lamp; at each successive step a lamp is added in parallel with the first one until all are in, and the last position of the lever cuts out the lamps, leaving the armature in circuit direct.

The lamps should be mounted on the base with the lever and contacts, and it is preferable, though not particularly urgent, that the switch *S* be

mounted on that base also. The sketch shows the lever in the "off" position; the switch, *S*, should never be closed, except when the lever *L* is in this position. If the reader desires to make the arrangement automatic he need only add a retractile spring to pull the lever *L* to the "off"

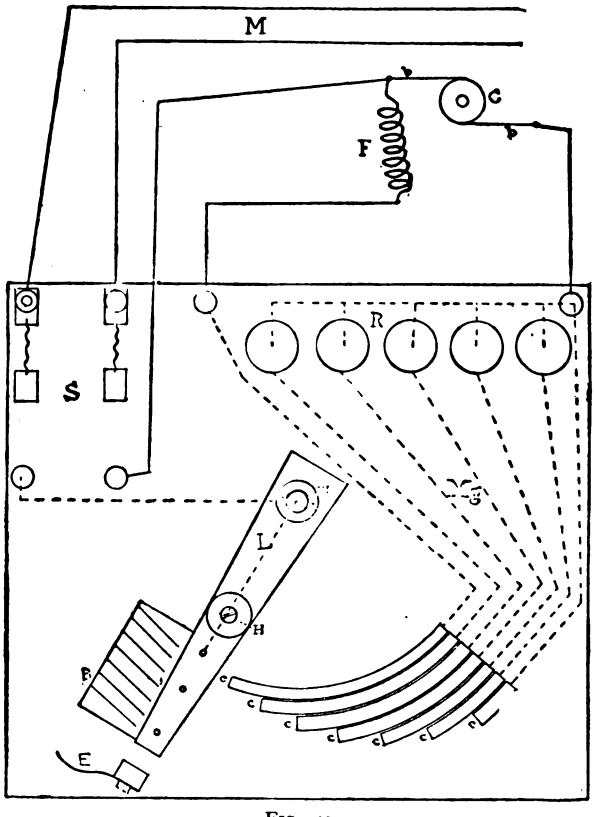


FIG. 49

position; a bar of iron $\frac{1}{8}$ in. by $\frac{1}{4}$ in. by 2 ins. on the right-hand edge of the lever, and a small magnet connected in series with the field, *F*, and located on the base about *Mg*, in such a position that it will hold the lever, by means of the bar of iron, when it is brought to the "on" position.

CHAPTER VII

ONE HORSE-POWER FOUR-POLAR MOTOR WITH DRUM ARMATURE

FOR the four-polar 1 horse-power motor here described only one type of field magnet is shown, namely, the familiar ring yoke with radial magnet poles. This type combines more good points than any other, hence the limitation to the one type. A choice is given, however, between cast iron and cast steel. The armature construction is the same for both types of field magnet, the only difference being in the length of the core along the shaft, and, consequently, the length of the shaft.

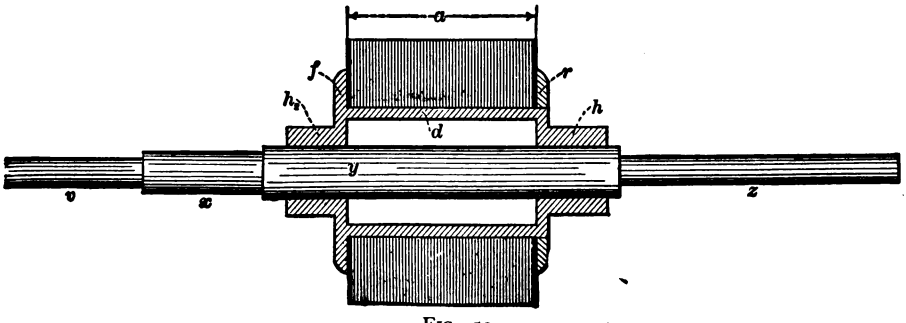


FIG. 50

Fig. 50 shows the shaft and a cross-sectional view of the armature core. The discs are mounted on a cast-iron drum, *d*, which has a flange *f*, and a hub, h_2, at one end, and a hub, *h*, at the other end. Fig. 51 gives a transverse cross-sectional view of the drum, and Fig. 52 is a perspective view, from the flangeless end. The wall of the drum is thickened at two places, diametrically opposite, as shown in Fig. 51. This is necessary on one side in order to provide sufficient metal under the key-seat; it is necessary on the opposite side to obtain a mechanical balance.

The discs are held endwise by a clamping ring, *r*, which may be either screwed onto the end of the drum, *d*, or held on by four flat-headed screws

with large heads. The discs are held from turning by a key. At each end of the magnetic core a disc of fiber, indicated by heavy black lines, should be placed. These discs must be exactly like the core discs, except that they are 1-16 in. thick.

The core discs are $5\frac{1}{2}$ ins. in diameter and 1-40 in. thick, with 3:

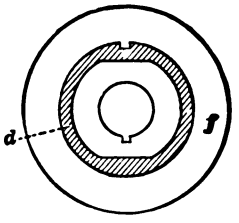


FIG. 51

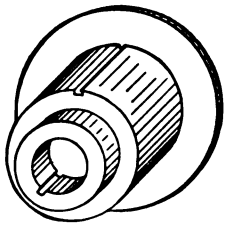


FIG. 52

slots, each $\frac{1}{4}$ in. wide and 9-16 in. deep. The slots have parallel sides. The discs must be of the best annealed low-carbon steel; the hole in the center is 3 ins. in diameter, key-seated. The flange, *f*, and the clamping-ring, *r*, must have their outer edges rounded off to avoid cutting the insulation of the winding. The dimensions of the core drum are as below:

	INCHES
Length of drum, d	$4\frac{1}{4}$
Innner diameter of d	$2\frac{1}{2}$
Outer diameter of d	3
Diameter of flange, f, and ring, r	$4\frac{3}{8}$
Thickness of flange, f, and ring, r	$\frac{1}{4}$
Thickness of d at thickest point	$\frac{1}{2}$
Diameter of hubs, h and h_2	$1\frac{7}{8}$
Bore of hubs, h and h_2	$1\frac{1}{8}$
Length of hub, h	$1\frac{1}{4}$
Length of hub, h_2	1
Length, a, of disc portion of core	4

The shaft measurements are as follows:

At	v	x	y	z
Diameter, inches	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{8}$	$\frac{5}{8}$
Length, inches	3	$2\frac{1}{2}$	$7\frac{1}{2}$	6

The shoulders where *v* and *x* meet and where *y* and *z* meet should be slightly rounded off at the corner and filleted in the angle. A key should be used to fasten each hub to the shaft, but the machine will doubtless give satisfaction with only one key, that one being in the hub, *h*, at the pulley end.

Figs. 53 to 56 inclusive show end and side views and cross-sections of a journal pedestal and box. The two bearings are alike in every par-

ticular, and are made of cast iron. The base or foot is tooled to conform to the circle to which the pedestal seat, on the magnet frame, is machined, and is $\frac{1}{2}$ in. thick. The standard or pedestal consists of two ribs at right angles to each other, $\frac{1}{2}$ in. thick and having curved edges, as shown. The box is of the ring-oiling type, with a single ring hung about midway of the journal; the bushing is easily made from thin brass tubing, $\frac{7}{8}$ in. outside diameter, and with a very thin wall (not over 1-32 in.), babbitted to fit the shaft and having a slot $\frac{3}{8}$ in. wide cut half way through it, nearly midway between its ends; accurately, slot must be $\frac{1}{4}$ in. nearer one end than the other. The bushing is $2\frac{3}{4}$ ins. long; the oil ring is made of brass, $1\frac{1}{2}$ ins. in diameter inside, 1 11-16 ins. diameter outside, and $\frac{1}{4}$ in. wide along the shaft. Reference to the side views of the journal pedestal will show a slot in the upper wall of the box portion, through which the oil ring is inserted before putting in the bushing. A cover should be provided for this slot to keep out dust, etc. The dimensions of the journal pedestals are as follows:

	INCHES
B — Radius of arc, pedestal seat	$5\frac{1}{2}$
g — Length of circular oil reservoir	2
i — Length of journal box	3
Bore of journal box	$\frac{7}{8}$
j — Diameter of oil reservoir	$2\frac{3}{8}$
Internal diameter of oil reservoir	2
J — Width of pedestal foot	3
k — Length of pedestal foot	3

The bore of the box portion of the pedestal must, of course, be made to fit snugly the outer diameter of the tubing used for a bushing, as the

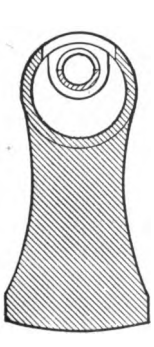


FIG. 53

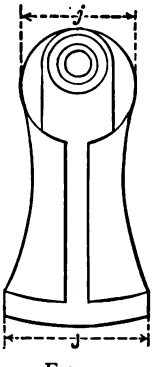


FIG. 54

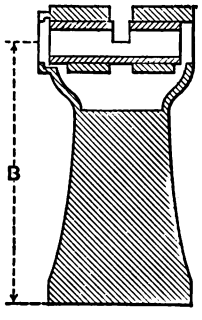


FIG. 55

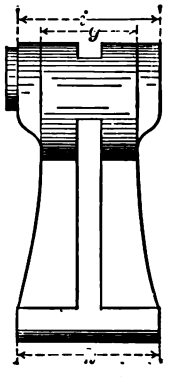


FIG. 56

wall of the latter is too thin to admit of turning it down to fit a predetermined bore in the pedestal. After boring the pedestal to fit the bushing

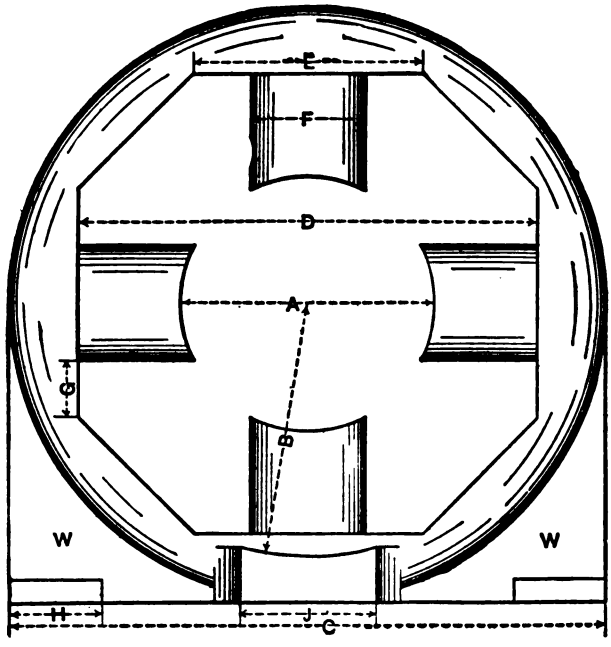


FIG. 57

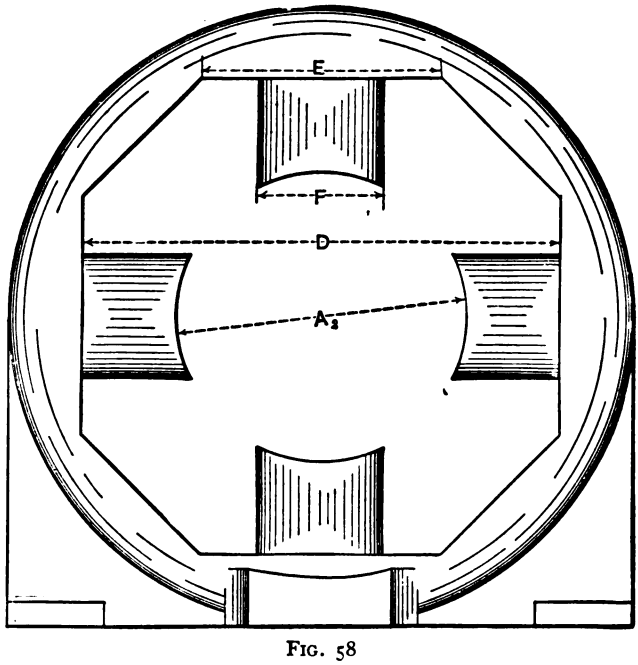


FIG. 58

it should be mounted on a mandrel and its base turned to the radius ***B***, of $5\frac{1}{2}$ ins., which is the same as the radius of the circle of the foot on the magnet frame. Each pedestal should be fastened to the foot with four $\frac{1}{4}$-in. cap screws.

Of the two field magnets shown, the cast-iron one will be found much easier to make because there is less tooling to be done and iron castings

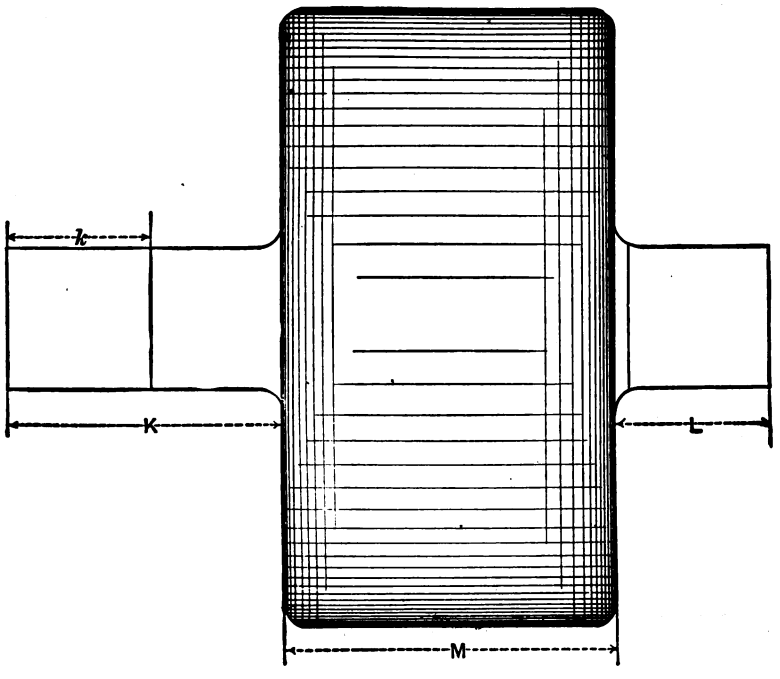


FIG. 59

are smoother than steel, requiring little or no finishing elsewhere than the pedestal seats and pole faces. Fig. 57 shows the cast-iron magnet frame and Fig. 58 the cast-steel frame. Fig. 59 is a plan view of either frame and Fig. 60 is an edge view.

The measurements for the cast-iron magnet are as follows:

	INCHES
A — Bore of armature chamber	$5\frac{5}{8}$
B — Radius to which pedestal seat is bored	$5\frac{1}{2}$
C — Outer diameter of yoke ring	13
D — Distance between parallel inner faces of yoke ring	10
E — Width of plane surface behind coil	5
F — Width of magnet coil	$2\frac{1}{2}$
F_2 — Breadth of magnet core	4
G — Distance from core to angle of yoke	$1\frac{1}{4}$

H — Width of frame foot	2
H_2 — Length of double foot	$4\frac{1}{2}$
J — Width of pedestal lug and seat	3
K — Length of pedestal lug commutator side	$5\frac{3}{4}$
L — Length of pedestal lug pulley side	$3\frac{1}{4}$
k — Length of pedestal seat	3
M — Axial width of magnet yoke	7

Fig. 61 shows the cross-section of a magnet core, from which it will be seen that the corners of the core are rounded off. The radius of the curve here is $\frac{1}{4}$ in. The only machining that should be required for this

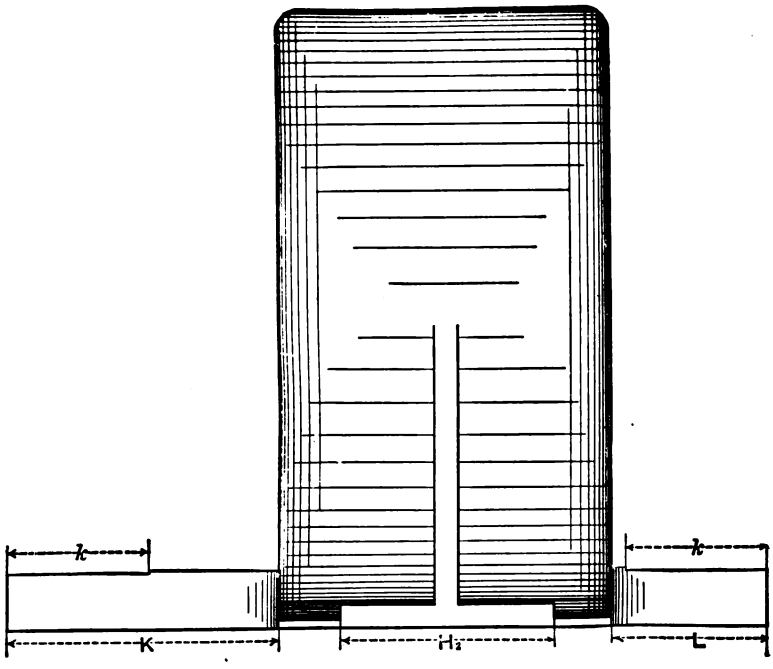


FIG. 60

frame is boring the armature chamber and pedestal seats and drilling 12 bolt-holes. The frame should be clamped to a lathe carriage with its center true with the lathe centers, and the boring done at one setting by means of a boring bar and tool. Both pedestal seats should be cut before the frame is moved from its original position.

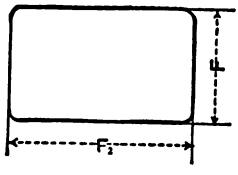


FIG. 61

The magnet must be made of the very best grade of iron obtainable; use Scotch pig if possible. It should be allowed to remain in the sand until it is cold, care being taken not to remove any of the sand around the magnet

portion until the casting is ready to come out. The longer of the two lugs might advantageously be placed uppermost in putting the pattern in the sand, and after the casting has been cooling for 24 hours the sand may be scraped away from the end of this lug so that its temperature may be noted.

The steel field magnet is much preferable if the reader has the skill and facilities to make it properly. The difference from the cast-iron magnet consists in making the magnet cores round instead of oblong, and putting on pole-shoes. The length of the machine is thereby reduced one inch, but all the transverse measurements remain unchanged. The magnet ends are machined, exactly as in the case of the cast-iron frame, but the bore, A_2, is greater, namely, $6\frac{1}{8}$ ins.

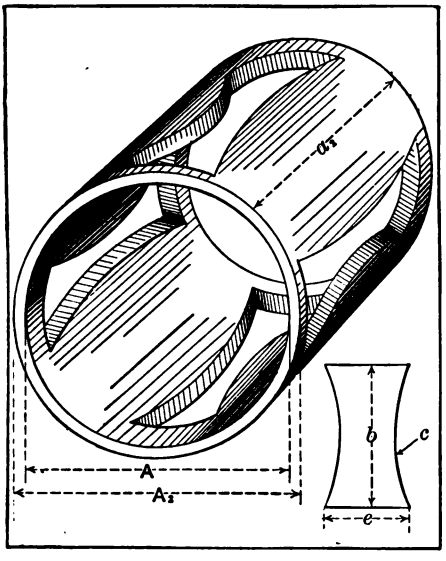


FIG. 62 FIG. 63

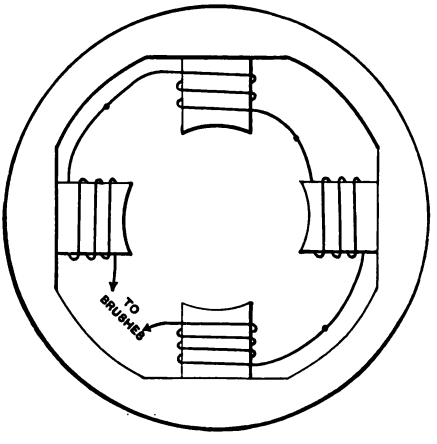


FIG. 64

The pole-pieces are made in one piece, called a polar-bushing, like Fig. 62, and this had better be done before the magnet is bored out. This bushing is a simple cylinder of cast iron with four openings in its wall, equidistant from each other. Fig. 63 shows the exact shape of each of these openings. The measurements of the bushing are these:

	INCHES
A — Bore of bushing, finished	$5\frac{5}{8}$
A_2 — Diameter of bushing, finished	$6\frac{1}{8}$
a_2 — Length of bushing, finished	$3\frac{1}{4}$
b — Length of openings in wall	3
c — Radius of curve, side of opening	4
e — Maximum width of opening	$1\frac{3}{4}$

The casting for this bushing should be about $3\frac{5}{8}$ ins. long, $6\frac{3}{8}$ ins. in diameter, and $5\frac{3}{8}$ ins. bore in the rough. After it has been turned down to the finished diameter, mount the magnet frame and bore out its polar circle to such a size that the bushing is a snug fit — not quite a driving fit, but tight enough to prevent turning by hand. Then insert the bushing so that the openings in its sides come half way between the magnet cores, and scribe the outlines of two opposite cores on its surface.

Remove the bushing and set a steel pin at each extremity of each ellipse scribed on the surface. Then put the bushing back and bore it out for the armature chamber. The pins will take up against the edges of the magnet cores and prevent the bushing from turning. After boring it out, turn off the ends of the bushing so as to leave the connecting webs from pole-piece to pole-piece $\frac{1}{8}$ in. thick.

The objection to this magnet is the difficulty of fitting the bushing to the magnet with sufficient accuracy to make good magnetic contact and still leave it loose enough to permit removal without breaking the thin connecting webs. This could be obviated by bolting the pole-pieces to the ends of the magnet cores by means of long, slender machine screws, put in from the outside of the yoke through holes in the centers of the magnet cores. Then the connecting webs could be sawed out entirely, leaving each pole-shoe independent of the others. This construction is also magnetically preferable, and if the builder has means for drilling a $\frac{1}{4}$-in. hole from the outside of the ring to the end of the magnet core (a distance of $3\frac{1}{2}$ ins.), the pole-shoes should be held on this way.

With the steel magnet the following measurements must be substituted for those previously given:

	INCHES
F — Diameter of magnet core	$2\frac{5}{8}$
M — Width of magnet yoke	6
a — Length of disc part of core	3
Length of drum, d	$3\frac{1}{4}$
Outer diameter of drum, d	$2\frac{3}{4}$
Inner diameter of drum, d	$2\frac{1}{4}$

The four field coils for the cast-iron magnet frame described in the preceding chapter are of No. 21 single-cotton-covered magnet wire. The depth of the winding must be $1\frac{1}{4}$ ins., as nearly as possible, and the length along the core should be 2 ins. Careful and close winding should give 40 layers of wire, with 58 turns to a layer. Whatever number of turns the reader may obtain, that number must be precisely the same in all four coils. In order to attain uniformity the coils should be wound upon a frame and the turns religiously counted.

It will be found advantageous to tie a knot in the starting end of each coil before taping it, so that it may be identified afterward. The coils

must be connected up as shown by the diagram, Fig. 64, so that the starting end of one connects to the finishing end of its neighbor. This presupposes that all four are wound in the same direction, as they should be.

The coils for the cast-steel magnet are of No. 24 single-cotton-covered wire, $1\frac{1}{8}$ ins. deep and $1\frac{7}{8}$ ins. long. Good winding will enable the reader to put on 50 layers of wire and 75 turns to a layer. As in the previous case, however, the depth in inches is the essential point, though it is advantageous to get as many layers in that depth as possible. The coils are, of course, wound, insulated, and connected up exactly like the oblong coils of the cast-iron frame.

The armature core for either of the magnet frames will contain 32 coils; each coil consists of No. 21 double-cotton-covered wire, wound 5 turns wide by 4 layers deep. Each slot contains one side of each of two coils, so that the cross-section of the winding in a slot will be as in Fig. 65, except that the wire will lie closer together than the sketch indicates. All armature coils should be wound on a forming bobbin so that they will all be exactly alike. Fig. 66 shows what the essential dimensions should be. The width of the hollow of the coil is the same for both armature cores. As the armature core to be used with the steel magnet is an inch shorter than the other one, the coils for this core must be an inch shorter; hence the two dimensions for coil lengths.

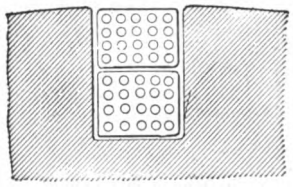


FIG. 65

Fig. 67 is a winding diagram and shows the first four coils in position. The coils are indicated by a single line across the head and dots in the slots for simplicity. The builder should note that the left-hand side of each coil is in the bottom of the slot and the right-hand side is on top; this should be true of every coil. The starting ends should be knotted for identification, and all the knotted ends should occupy the same relative position on the core. For smoothness of finished heads the coils should be put on the core in the following order:

Coils 1, 2, 3, 4 in Slots 1– 9, 9–17, 17–25, 25–1
Coils 5, 6, 7, 8 in Slots 2–10, 10–18, 18–26, 26–2
Coils 9, 10, 11, 12 in Slots 3–11, 11–19, 19–27, 27–3
Coils 13, 14, 15, 16 in Slots 4–12, 12–20, 20–28, 28–4
Coils 17, 18, 19, 20 in Slots 5–13, 13–21, 21–29, 29–5
Coils 21, 22, 23, 24 in Slots 6–14, 14–22, 22–30, 30–6
Coils 25, 26, 27, 28 in Slots 7–15, 15–23, 23–31, 31–7
Coils 29, 30, 31, 32 in Slots 8–16, 16–24, 24–32, 32–8

If put in properly, the coils will give a regular sequence of knotted ends and straight ends, one each projecting from each slot. The connections

to the commutator are then simple. Carry all the knotted ends straight out to the commutator, and the straight ends one segment less than a quarter circle backwards from their corresponding knotted ends. Thus,

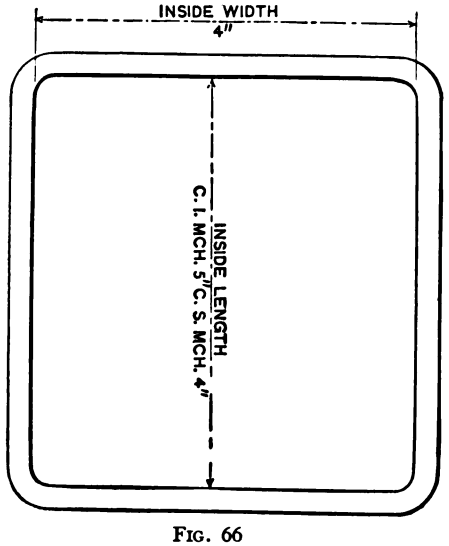


FIG. 66

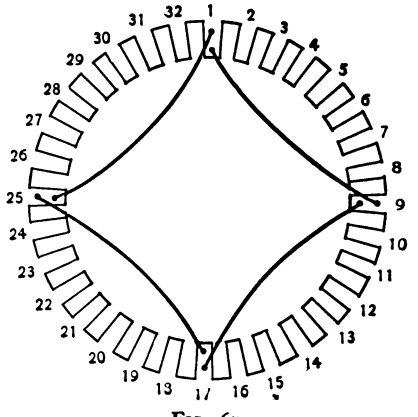


FIG. 67

the knotted end from slot No. 1 goes to commutator segment No. 1 (see Fig. 68), and so on, all the way around. Then the straight ends go to the commutator as follows:

From Slot No. 1 to Segment No. 26
From Slot No. 2 to Segment No. 27
From Slot No. 3 to Segment No. 28
From Slot No. 4 to Segment No. 29
From Slot No. 5 to Segment No. 30
From Slot No. 6 to Segment No. 31
From Slot No. 7 to Segment No. 32
From Slot No. 8 to Segment No. 1
From Slot No. 9 to Segment No. 2
From Slot No. 10 to Segment No. 3
From Slot No. 11 to Segment No. 4
From Slot No. 12 to Segment No. 5
From Slot No. 13 to Segment No. 6
From Slot No. 14 to Segment No. 7
From Slot No. 15 to Segment No. 8
From Slot No. 16 to Segment No. 9
From Slot No. 17 to Segment No. 10
From Slot No. 18 to Segment No. 11
From Slot No. 19 to Segment No. 12
From Slot No. 20 to Segment No. 13
From Slot No. 21 to Segment No. 14
From Slot No. 22 to Segment No. 15
From Slot No. 23 to Segment No. 16
From Slot No. 24 to Segment No. 17

From Slot No. 25 to Segment No. 18
From Slot No. 26 to Segment No. 19
From Slot No. 27 to Segment No. 20
From Slot No. 28 to Segment No. 21
From Slot No. 29 to Segment No. 22
From Slot No. 30 to Segment No. 23
From Slot No. 31 to Segment No. 24
From Slot No. 32 to Segment No. 25

The commutator must have 32 segments, as indicated by Fig. 68, and should be purchased already built for assured satisfaction. The brush surface of the commutator must be $1\frac{1}{4}$ ins. long at least, so that carbon brushes 1 in. wide and $\frac{1}{4}$ in. thick can be used. The diameter of the barrel of the commutator should not be less than 3, and preferably 4 ins. The brush-holders and yoke may be copied advantageously from any of the standard machines now on the market. Four brushes must be used, and the two diametrically opposite are connected together, as shown by Fig. 69.

The windings just described are for machines to work on a 110–115-volt circuit. If windings for 220–230 volts are desired the armature coils should be of No. 25 wire, each coil five layers deep and eight turns wide, making ten layers of wire per slot. The field coils of the cast-iron magnet must be of No. 24 s.c.c. wire, wound to the dimensions specified above,

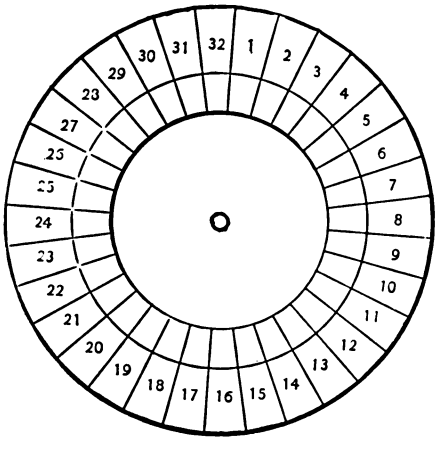


FIG. 68

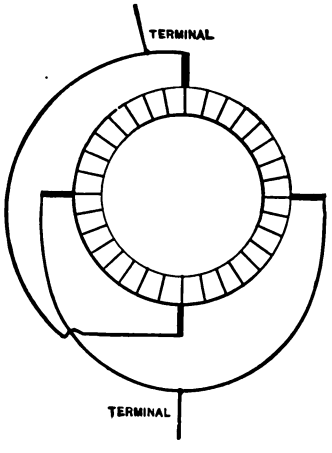


FIG. 69

namely, $1\frac{1}{4}$ ins. deep and 2 ins. long. The coils for the cast-steel magnet will be of No. 27 wire wound to a depth of $1\frac{1}{8}$ ins. and a length $1\frac{7}{8}$ ins.

The principal magnetic and electrical data of the two machines are as follows:

115-VOLT MOTOR

	Cast iron.	Cast steel.
Resistance armature winding	1 ohm	0.9
Normal armature currents	9 amp.	9 amp.
Approximate speed	1600	1600
Density in field cores	48,000	93,000
Density in air gap	27,500	37,500
Efficiency, assuming 10 per cent friction and windage	70 per cent	75 per cent

As in the preceding case, it is by far preferable to buy a starting box from one of the standard rheotsat manufacturers. If the reader insists upon having a home-made one, however, the arrangement shown by Fig. 49 and described on pages 51 and 52 will answer.

CHAPTER VIII

TWO HORSE-POWER FOUR-POLAR MOTOR WITH TWO-PATH DRUM ARMATURE

FOR this motor, as in the preceding design, only one type of field magnet is shown, namely, the familiar ring yoke with radial magnet poles; a choice is given between cast-iron and cast-steel field magnets. The armature construction is identical for both types of magnet, there being a difference only in the length of the armature and shaft.

Fig. 70 shows the shaft and a cross-sectional view of the armature core. The discs are mounted on a cast-iron drum, *d*, which has a flange,

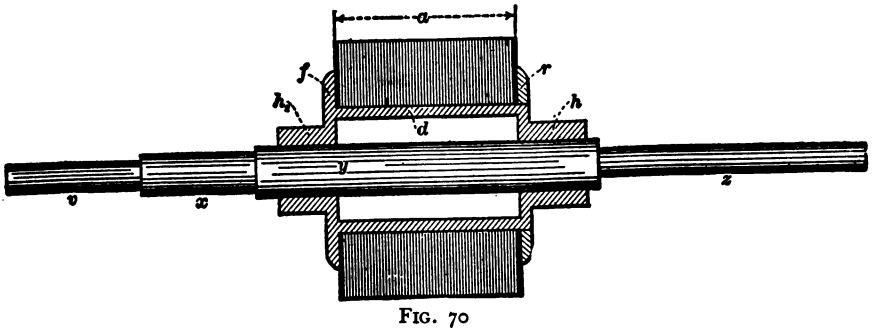


FIG. 70

f, and a hub, h_2, at one end, and a hub, *h*, at the other end. Fig. 71 gives a transverse cross-sectional view of the drum, and Fig. 72 is a perspective view, from the flangeless end. The wall of the drum is thickened at two places, diametrically opposite, as shown in Fig. 71. This is necessary on one side in order to provide sufficient metal under the key-seat; it is necessary on the opposite side to obtain a mechanical balance.

The discs are held endwise by a clamping ring, *r*, which may be either screwed onto the end of the drum, *d*, or held on by four flat-headed screws with large heads. The discs are held from turning by a key. At each end of the magnetic core a disc of fiber, indicated by heavy black lines,

should be placed. These discs must be exactly like the iron discs, except that they are 1-16 in. thick.

The steel core discs are $6\frac{7}{8}$ ins. outside diameter and 1-40 in. thick, with 43 slots, each $\frac{1}{4}$ in. wide and 9-16 in. deep. The slots have parallel sides. The discs must be of the best charcoal iron; the hole in the center is $3\frac{5}{8}$ ins. in diameter, key-seated. The flange, *f*, and the clamping ring, *r*, must have their outer edges rounded off to avoid cutting the insulation of the winding. The dimensions of the core drum are as below:

Length of drum, d	$5\frac{1}{16}$
Inner diameter of d	3
Outer diameter of d	$3\frac{5}{8}$
Diameter of flange, f, and ring, r	$5\frac{3}{4}$
Thickness of flange, f, and ring, r	$\frac{5}{16}$
Thickness of d at thickest point	$\frac{1}{2}$
Diameter of hubs, h and h_2	2
Bore of hubs, h and h_2	$1\frac{1}{4}$
Length of hub, h	$1\frac{1}{2}$
Length of hub, h_2	$1\frac{1}{4}$
Length of a, of disc portion of core	$4\frac{3}{4}$

The shaft measurements are as follows:

	At	v	x	y	z
Diameter, inches		$\frac{3}{4}$	1	$1\frac{1}{4}$	$\frac{3}{4}$
Length, inches		$3\frac{5}{8}$	3	9	$7\frac{1}{4}$

The shoulders where *v* and *x* meet and where *y* and *z* meet should be slightly rounded off at the corner and filleted in the angle. A key should be used to fasten each hub to the shaft, but the machine will doubtless give satisfaction with only one key, that one being in the hub, *h*, at the pulley end. The hub, *h*, must be exactly $\frac{1}{4}$ in. from the shoulder on the shaft.

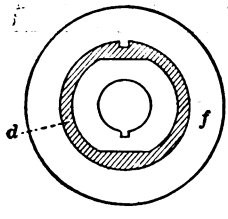


FIG. 71

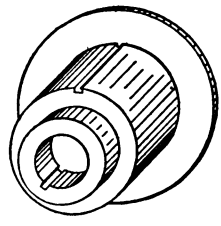


FIG. 72

Figs. 73 to 76, inclusive, show end and side views and cross-sections of a journal pedestal and box. The two bearings are alike in every particular, and are made of cast iron. The base or foot is tooled to conform to the circle to which the pedestal seat, on the magnet frame, is machined, and is $\frac{5}{8}$ in. thick. The standard or pedestal consists of two ribs at right angles to each other, $\frac{5}{8}$ in. thick and having curved edges, as shown. The box is of the ring-oiling type, with a single ring hung about midway of the journal; the bushing is easily made from thin brass tubing, 1 in. outside diameter, and with a very thin wall (not over 1-32 in.), babbitted to fit the shaft and having

a slot 7-16 in. wide cut half way through it, nearly midway between its ends; accurately, the slot must be $\frac{1}{4}$ in. nearer one end than the other. The bushing is $3\frac{3}{8}$ ins. long; the oil ring is made of brass, 2 ins. in diameter inside, $2\frac{1}{4}$ ins. diameter outside, and $\frac{3}{8}$ in. wide along the shaft. Reference to the side views of the journal pedestal will show a slot in the

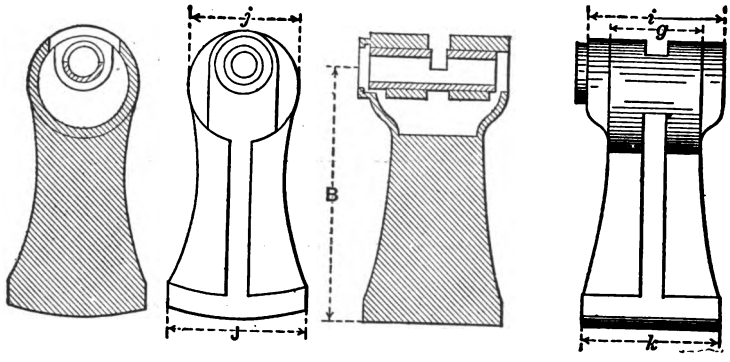


FIG. 73 FIG. 74 FIG. 75 FIG. 76

upper wall of the box portion, through which the oil ring is inserted before putting in the bushing. A cover should be provided for this slot to keep out dust, etc. The dimensions of the journal pedestals are as follows:

	INCHES
B — Radius of arc, pedestal seat	6
g — Length of circular oil reservoir	2
i — Length of journal box	$3\frac{5}{8}$
Bore of journal box	1
j — Diameter of oil reservoir	$2\frac{7}{8}$
Internal diameter of oil reservoir	$2\frac{1}{2}$
J — Width of pedestal foot	$3\frac{5}{8}$
k — Length of pedestal foot	$3\frac{5}{8}$

The bore of the box portion of the pedestal must, of course, be made to fit snugly the outer diameter of the tubing used for a bushing, as the wall of the latter is too thin to admit of turning it down to fit a predetermined bore in the pedestal. After boring the pedestal to fit the bushing it should be mounted on a mandrel and its base turned to the radius *B*, of 6 ins., which is the same as the radius of the circle of the foot on the magnet frame. Each pedestal should be fastened to the foot with four 5-16-in. cap screws.

Of the two field magnets shown, the cast-iron machine will be found easier to make because there is less tooling to be done and iron castings are smoother than steel, requiring little or no finishing elsewhere than

the pedestal seats and pole faces. Fig. 77 shows the cast-iron magnet frame and Fig. 78 the cast-steel frame. Fig. 79 is a plan view of either frame and Fig. 80 is an edge view.

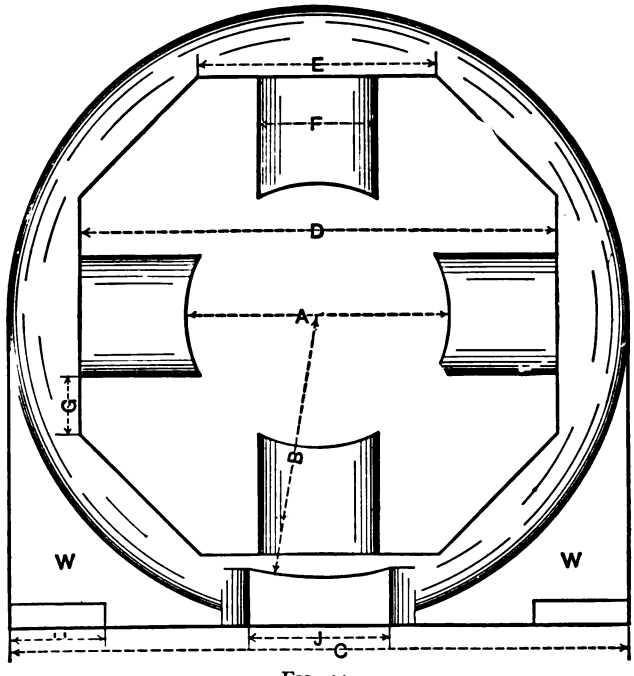


FIG. 77

The measurements for the cast-iron magnet are as follows:

	INCHES
A — Bore of armature chamber	7
B — Radius to which pedestal seat is bored	$6\frac{5}{8}$
C — Outer diameter of yoke ring	$15\frac{5}{8}$
D — Distance between parallel inner faces of yoke ring	12
E — Width of plane surface behind coil	6
F — Width of magnet core	3
F_2 — Breadth of magnet core	$4\frac{1}{2}$
G — Distance from core to angle of yoke	$1\frac{1}{4}$
H — Width of frame foot	$2\frac{1}{2}$
H_2 — Length of double foot	5
J — Width of pedestal lug and seat	$3\frac{5}{8}$
K — Length of pedestal lug, commutator side	$6\frac{7}{8}$
L — Length of pedestal lug, pulley side	$3\frac{7}{8}$
k — Length of pedestal seat	$3\frac{5}{8}$
M — Axial width of magnet yoke	$8\frac{7}{16}$

Fig. 81 shows the cross-section of a magnet core, from which it will be seen that the corners of the core are rounded off. The radius of the

curve here is 0.3 in. The only machining that should be required for this frame is boring the armature chamber and pedestal seats and drilling 12 bolt-holes. The frame should be clamped to a lathe carriage with

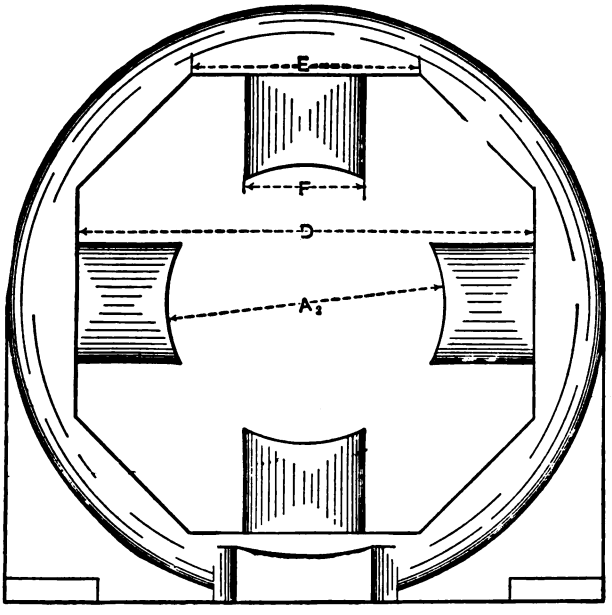


FIG. 78

its center true with the lathe centers, and the boring done at one setting by means of a boring bar and tool. Both pedestal seats should be cut before the frame is moved from its original position.

The magnet must be made of the very best grade of iron obtainable; use Scotch pig if possible. It should be allowed to remain in the sand until it is cold, care being taken not to remove any of the sand around the magnet portion until the casting is ready to come out. The longer of the two lugs might advantageously be placed uppermost in putting the pattern in the sand, and after the casting has been cooling for 24 hours the sand may be scraped away from the end of this lug so that its temperature may be noted.

The cast-steel field magnet is much preferable, if the reader has the skill and facilities to make it properly. The difference from the cast-iron magnet consists in making the magnet cores round instead of oblong, and putting on pole-shoes. The length of the machine is thereby reduced $1\frac{1}{4}$ ins., but all the transverse measurements remain unchanged. The

magnet ends are machined exactly as in the case of the cast-iron frame, but the bore, A_2, is greater, namely, $7\frac{1}{2}$ ins.

The pole-pieces are made in one piece, called a polar-bushing, like Fig. 82, and this had better be done before the magnet is bored out. This bushing is a simple cylinder of cast iron with four openings in its wall, equidistant from each other. Fig. 83 shows the exact shape of each of

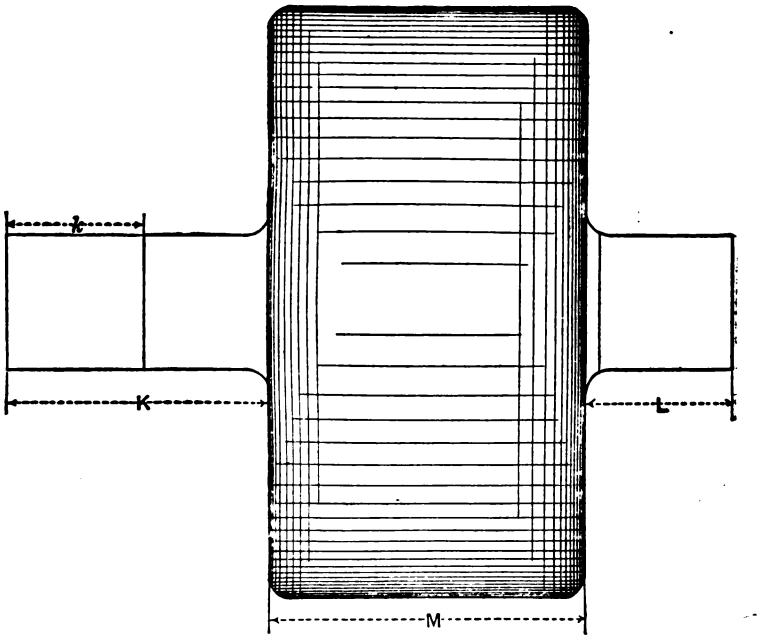


FIG. 79

these openings. The measurements of the bushing are these:

	INCHES
A_2 — Diameter of bushing, finished	$7\frac{1}{2}$
A — Bore of bushing, finished	7
a_2 — Length of bushing, finished	$3\frac{3}{4}$
b — Length of openings in walls	$3\frac{1}{2}$
c — Radius of curve, side of opening	$4\frac{1}{2}$
e — Maximum width of opening	$2\frac{1}{2}$

The casting for this bushing should be about 4 ins. long, $7\frac{3}{4}$ ins. in diameter, and $6\frac{3}{4}$ ins. bore, in the rough. After it has been turned down to the finished diameter, mount the magnet frame and bore out its polar circle to such a size that the bushing is a snug fit — not quite a driving fit, but tight enough to prevent turning by hand. Then insert the bushing

so that the openings in its sides come half way between the magnet cores, and scribe the outlines of two opposite cores on its surface.

Remove the bushing and set a steel pin at each extremity of each ellipse scribed on the surface. Then put the bushing back and bore it out for the armature chamber. The pins will take up against the edges of the magnet cores and prevent the bushing from turning. After boring

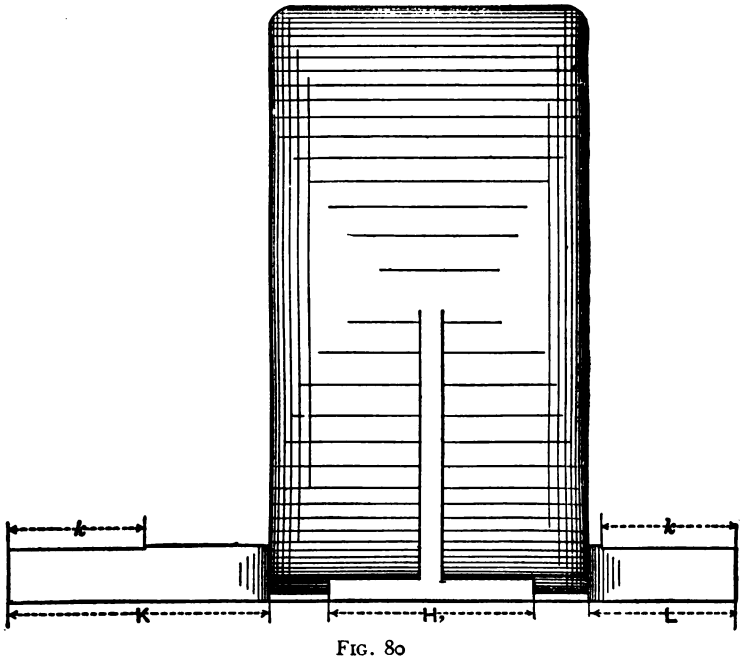


FIG. 80

it out, turn off the ends of the bushing so as to leave the connecting webs from pole-piece to pole-piece $\frac{1}{8}$ in. thick, measured axially.

The objection to this magnet is the difficulty of fitting the bushing to the magnet with sufficient accuracy to make good magnetic contact and still leave it loose enough to permit removal without breaking the thin connecting webs. This could be obviated by bolting the pole-pieces to the ends of the magnet cores by means of long, slender machine screws, put in from the outside of the yoke through holes in the centers of the magnet cores. Then the connecting webs could be sawed out entirely, leaving each pole-shoe independent of the others. This construction is also magnetically preferable, and if the builder has

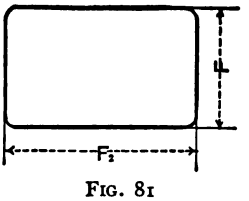


FIG. 81

means for drilling $\frac{1}{4}$-in. holes through the magnet cores from the outside of the yoke ring to the inside of the bushing (a distance of $4\frac{3}{8}$ ins.), the pole-shoes should be held on this way.

With the steel magnet the following measurements must be substituted for those previously given:

	INCHES
F — Diameter of magnet core	$2\frac{7}{8}$
M — Width of magnet yoke	$7\frac{3}{16}$
a — Length of disc part of core	$3\frac{1}{2}$
Length of drum, d	$3\frac{13}{16}$
Length of part y, of shaft	$7\frac{1}{4}$

This is to say, the machine must be exactly $1\frac{1}{4}$ ins. shorter, axially.

The four field coils for the cast-iron magnet frame are of No. 22 single-cotton-covered magnet wire. The depth of the winding must be $1\frac{1}{2}$ ins., as nearly as possible, and the length along the core should be $2\frac{1}{4}$ ins. Careful and close winding should give 50 layers of wire, with 70 turns to a layer. Whatever number of turns the reader may obtain, that number must be precisely the same in all four coils. In order to attain uniformity the coils should be wound upon a frame and the turns religiously counted.

It will be found advantageous to tie a knot in the starting end of each

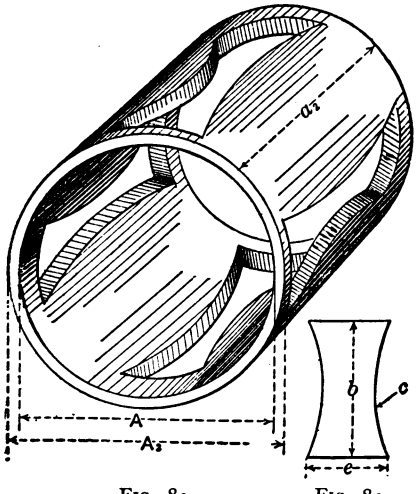


FIG. 82 FIG. 83

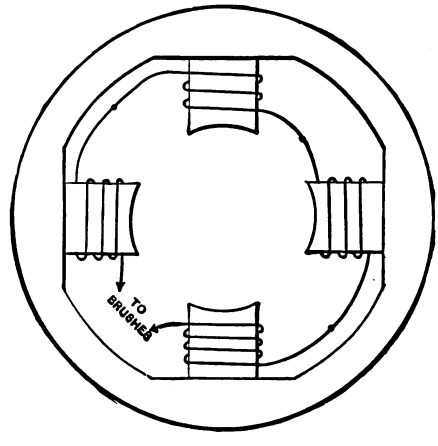


FIG. 84

coil before taping it so that it may be identified afterward. The coils must be connected up as shown by the diagram, Fig. 84, so that the starting end of one connects to the finishing end of its neighbor. This presupposes that all four are wound in the same direction, as they should be.

The coils for the cast-steel magnet are of No. 23 single-cotton-covered wire, $1\frac{1}{2}$ ins. deep and 2 ins. long. Good winding will enable the reader to put on 56 layers of wire and 70 turns to a layer. As in the previous case, however, the depth in inches is the essential point, though it is advantageous to get as many layers in that depth as possible. The coils are, of course, wound, insulated, and connected up exactly like the oblong coils of the cast-iron frame.

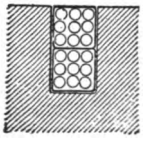


FIG. 85

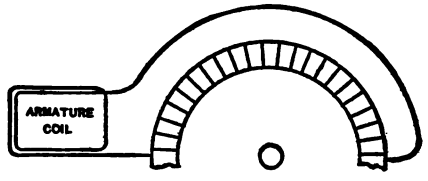


FIG. 88

The armature core for either of the magnet frames will contain 43 coils; each coil consists of No. 16 double-cotton-covered wire, wound three turns wide by three layers deep. Each slot contains one side of each of two coils, so that the cross-section of the winding in a slot will be as in Fig. 85.

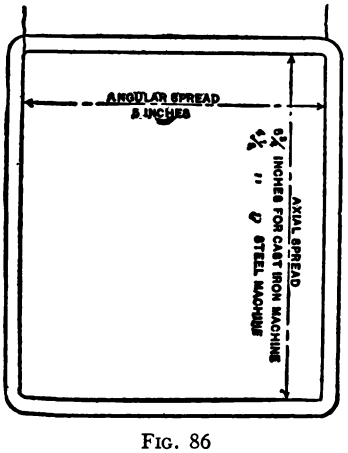


FIG. 86

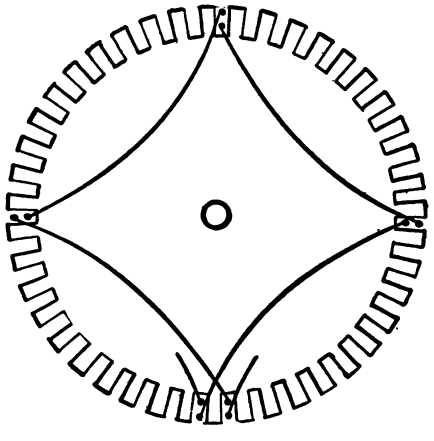


FIG. 87

All armature coils should be wound on a forming bobbin so that they will all be exactly alike. Fig. 86 shows what the essential dimensions should be. The width of the hollow of the coil is the same for both armature cores. As the armature core to be used with the steel magnet is $1\frac{1}{4}$ ins.

shorter than the other one, the coils for this core must be correspondingly shorter; hence the two dimensions for coil lengths.

Fig. 87 is a winding diagram and shows four coils in position. The coils are indicated by single lines across the head and dots in the slots for simplicity. The builder should note that the left-hand side of each coil is in the bottom of the slot and the right-hand side is on top; this should be true of every coil, but it is not imperative. The machine will work just as well if half of the coils are put on with both sides bottom and the other half on top of them, but the job will not be so neat on the armature heads. The spacing or pitch of the coils must be exactly as indicated — 10 slots in between the two sides of each coil.

The starting ends should be knotted for identification, and all the knotted ends should occupy the same relative position on the core. If put in properly, the coils will give a regular sequence of knotted ends and straight ends, one each projecting from each slot. The connections to the commutator are then simple. Carry all the knotted ends straight out to the commutator, and each straight end to a segment 22 bars from the one to which the knotted end is connected. Fig. 88 represents one coil connected, and shows that there are 21 segments between the two to which the coil ends go, reckoning around that side of the commutator nearest the coil itself. This spacing must be observed throughout.

The commutator must have 43 segments and should be purchased already built for assured satisfaction. The brush surface of the commutator must be $1\frac{1}{2}$ ins. long, at least, so that carbon brushes $1\frac{1}{4}$ ins. wide and $\frac{3}{8}$ in. thick can be used. The diameter of the barrel of the commutator should not be less than 4, and preferably 5 ins. The brush-holders and yoke may be copied advantageously from any of the standard machines now on the market. Only two brushes are to be used, and these set precisely a quarter of a circle apart, reckoning around the barrel of the commutator.

The windings just described are for machines to work on a 101–115-volt circuit. If windings for 220–230 volts are desired the armature coils should be of No. 19 wire, each coil 5 layers deep and 4 turns wide, making 10 layers of wire per slot. The field coils for the cast-iron magnet must be of No. 26 s.c.c. wire, wound to the dimensions specified above, namely, $1\frac{1}{2}$ ins. deep and $2\frac{1}{4}$ ins. long. The coils for the cast-steel magnet will be of No. 27 wire wound to a depth of $1\frac{1}{2}$ ins. and a length of 2 ins. For 500-volt service use No. 23 double-cotton-covered wire on the armature, six turns wide and seven layers deep, per coil; 84 wires per slot. On the cast-iron magnet use No. 29 double-covered wire and on the steel magnet No. 30.

The principal magnetic and electrical data of the two machines are below:

115-VOLT MOTOR

	Cast iron	Cast steel
Resistance armature winding	1 ohm	0.9
Normal armature current	18 amp.	18 amp.
Approximate speed	1325 r.p.m.	1325 r.p.m.
Density in field cores	33,700	70,000
Density in air-gap	26,000	38,000

CHAPTER IX

THREE HORSE-POWER MOTOR

THE motor design which forms the subject of this chapter, although somewhat similar to those described in Chapters VII and VIII, differs considerably in the constructional details of the magnet. Here a cast-iron ring and wrought-iron cores are employed with a view to simplifying the work as far as possible without sacrificing the efficiency of the machine, and also without making it unduly heavy. The cast-iron ring is preferably made in a single piece and the wrought-iron cores are turned to a very slight taper and drawn into holes in the yoke ring by means of a bolt and heavy washer from the outside. Unless the builder has excellent machine-shop facilities, however, and is an expert machinist, this construction will be found rather difficult, as it is necessary to have a perfect fit between the taper of the magnet core and that of the hole in which it is seated.

As an alternative the magnet frame can be cast in two pieces, the division being along the line, x, Fig. 91. If the motor is built in this way, each half must be chucked and the joint faced off fairly smooth, although it is not necessary to have a perfect joint, as no magnetic lines of force cross the break. After truing up the abutting faces of each half of the magnet ring the two halves should be clamped together with 1-32 in. of cardboard in between them and four straight holes bored for the reception of the field-magnet cores.

Fig. 89 is a semi-sectional elevation of the field magnet complete without the journal pedestals; a field-magnet core is shown by Fig. 90. The cast-iron pole-pieces must be accurately fitted to the ends of the cores and pinned permanently in place with iron pins. The magnet ring and pole-pieces should be of the best grade of pig iron obtainable. The magnet cores should be made of Norway wrought iron if obtainable; if not, of the mildest machinery steel. The corners of the pole-pieces should be heavily rounded so that no sharp edges are left. The length of the pole-piece parallel with the shaft is the same as its width at right angles to this dimension. The outside diameter of the magnet ring is 20⅛ ins.

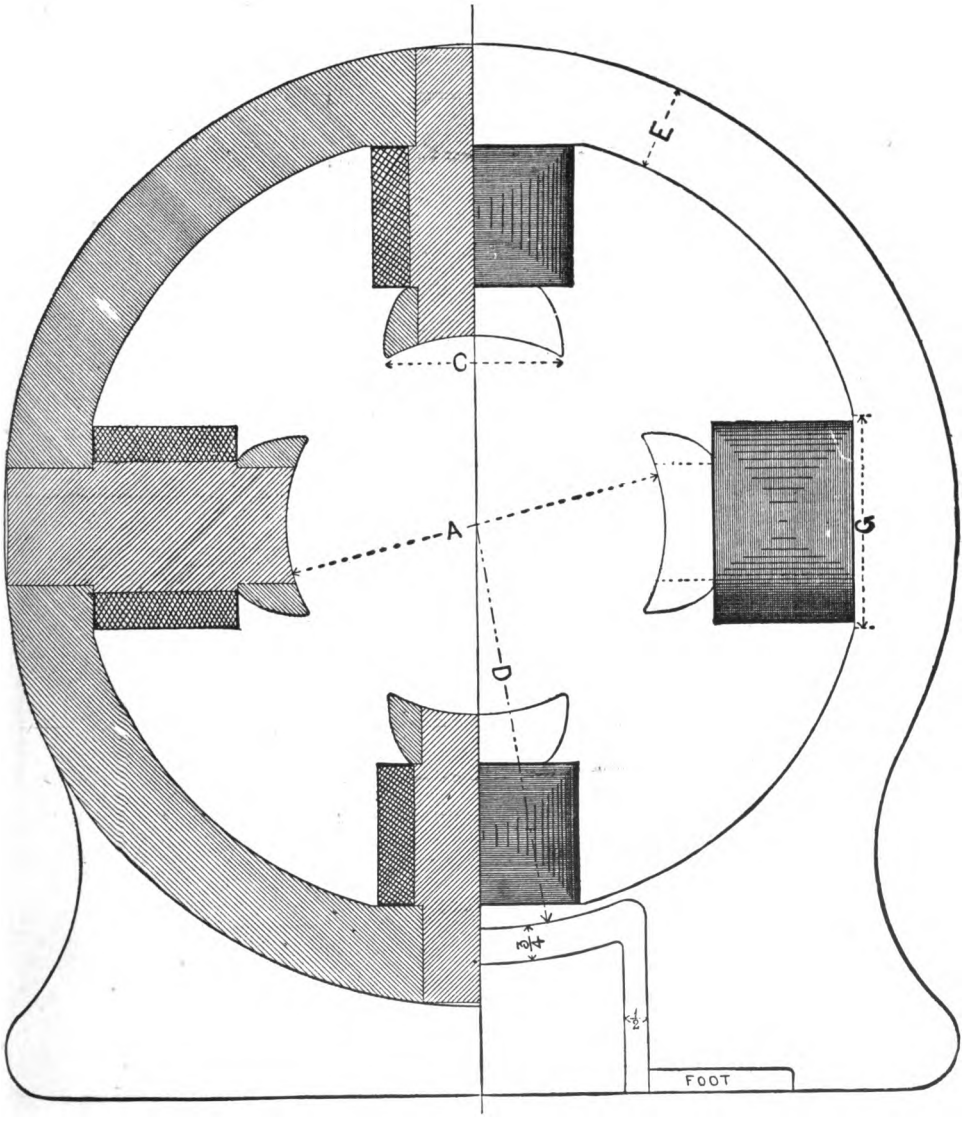


FIG. 89

The extreme breadth of the ring parallel with the shaft is 8 ins. The other dimensions are as below:

	INCHES
A — Bore of armature chamber	8
B — Axial length of pole-face	$3\frac{3}{4}$
C — Width of pole-piece, tip to tip, in a straight line	$3\frac{3}{4}$

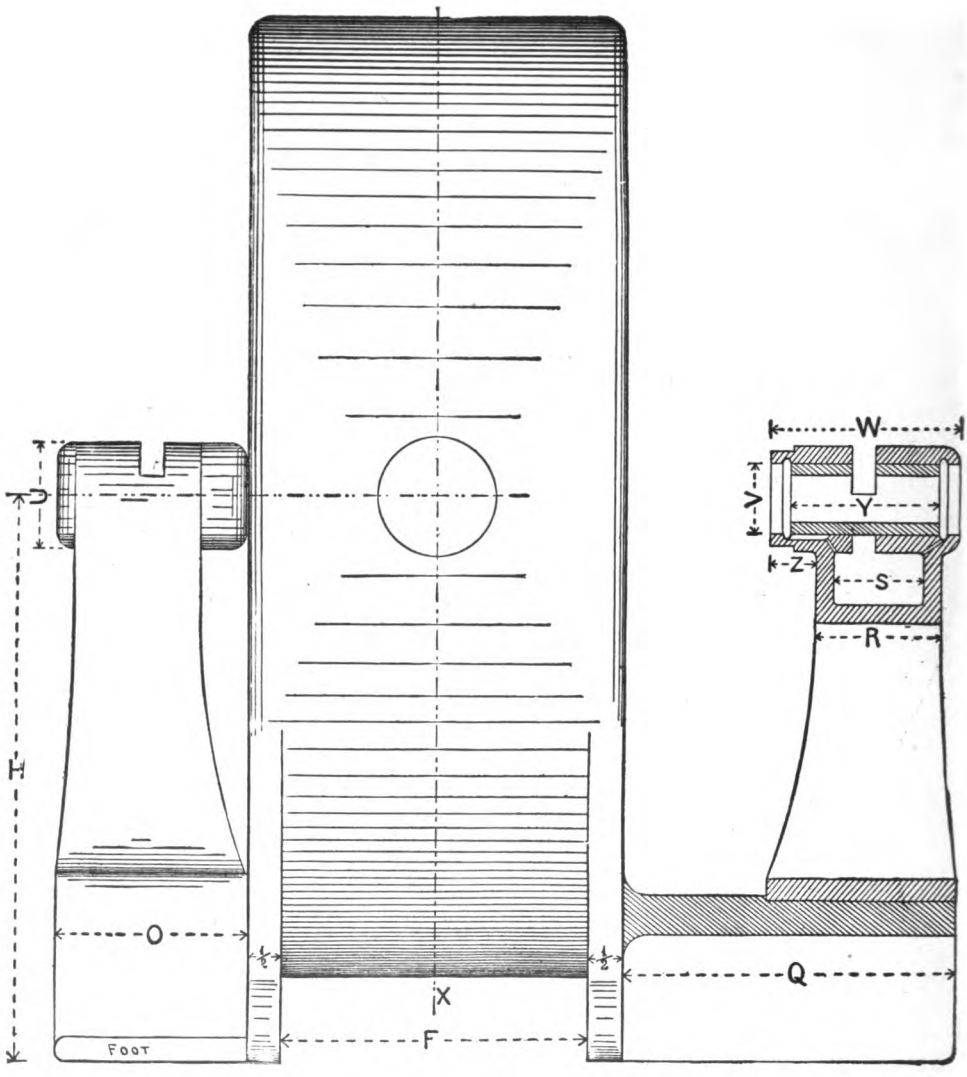


FIG. 91

D — Radius to which pedestal seat is cut	8½
E — Thickness of yoke ring	1½
F — Distance between ribs	7
G — Width of plane surface back of magnet coil	4½
H — Height, base line to armature center	12
O — Axial length of pedestal seat	4
P — Straight-line width of pedestal (width of pedestal seat is the same)	7
Q — Length of pedestal foot, commutator side	7

The dimensions of the magnet core (Fig. 90) are as follows:

At	y	m	p
Diameter, ins.	$2\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{1}{2}$
Length, ins.	2	3	$1\frac{1}{4}$

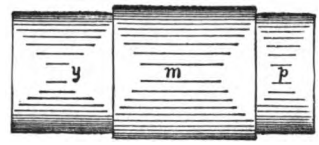


FIG. 90

Fig. 91 is an edge view of the field-magnet frame, including one journal pedestal shown in perspective and the other in cross-section. After fitting the magnet cores into place in the ring, the pole-pieces should be bored and the pedestal seats cut, at one setting of the frame. Fig. 92 is a cross-section of the armature core, showing the details of construction. The discs are mounted on a cast-iron drum, which is provided with a flange head and a hub, *J*, at one end, the other end being open. The discs are clamped in place by a cast-iron ring which is provided with a hub, *I*, similar to that at the other end of the drum, and drawn to place by means of six $\frac{1}{4}$-in. bolts passing through holes in the clamping ring and tapping into the end wall of the cast-iron drum. The center lines of two of these bolts are indicated by *b b*. The cast-iron drum should have a key-seat cut in it so that the discs may be positively driven.

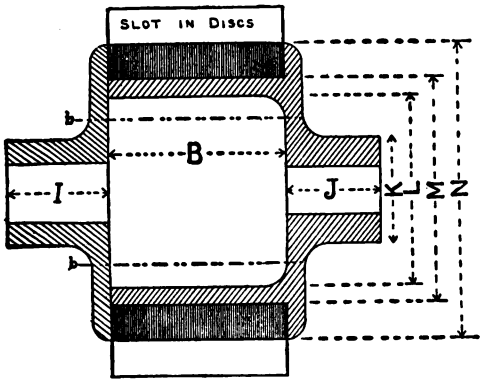


FIG. 92

Both the hub on the end of the drum and that on the clamping ring should be keyed to the shaft so that there will be no opportunity for displacement. At each end of the core structure a disc of fiber 1-16 in. thick should be provided, as indicated by the heavy black lines in the engraving. These discs must be toothed exactly like the core discs so that the ends of the magnetic core will be entirely covered. The iron core discs are $7\frac{3}{4}$ ins. in diameter, with a central hole $4\frac{3}{4}$ ins. in diameter, and 47 slots $\frac{1}{4}$ in. wide and $\frac{3}{4}$ in. deep; the slots have parallel sides. The discs must be of the best grade of low carbon steel, 1-40 in. thick. The dimensions of the armature core structure are as follows:

	INCHES
B — Internal length of drum	$3\frac{7}{8}$
I — Length of hub clear through	$2\frac{1}{8}$
Bore of this hub	$1\frac{1}{4}$
J — Length of hub clear through	2
Bore of this hub	1

K — Diameter of hubs	2¼
L — Internal diameter of core drum	4
M — Outer diameter of core drum	4¾
N — Diameter of flange and clamping ring	6¼
Thickness of flange and clamping ring	⅜

The two journal pedestals are exactly alike and made of ordinary cast iron. The base must be turned accurately to conform to the circle to which the pedestal seat on the magnet frame is machined. The standard, or pedestal, is an open frame of ½-in. metal; the box is of the ring-oiling type, with a single ring hung exactly midway of the journal. Fig. 93 is a transverse cross-section of the pedestal and box. The box is bushed; the bushing may consist of a brass casting turned to shape, or it may be made by babbitting a piece of thin brass tubing, the outer diameter of which is a snug fit in the box. The oil slot across the center of the box must be provided with a suitable covering to exclude dust. Each pedestal should be bolted to the magnet frame with two ⅜-in. cap screws. The pedestal and box measurements are below:

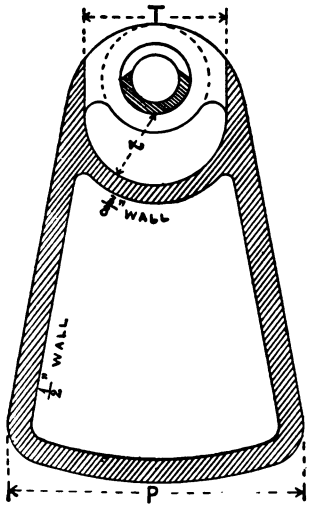


FIG. 93

	INCHES
P — Widest part of standard	7
R — Axial length of oil well	2¾
S — Inner length of oil well	2
T — Inner width of oil well	3
t — Radius line to indicate origin of circle	1½
U — Outside diameter of box	2¼
V — Inside diameter of box	1½
W — Outside length of box	4
Y — Length of bushing	3¼
Bore of bushing	1
Z — Projection of box beyond oil-well wall	1 5/16
Diameter of oil ring	2½
Bore of oil ring	1⅛
Width of oil ring	⅜

A bearing must be turned on the outside of the inner end of the pedestal on the commutator side of the machine, as indicated in Fig. 91, to accommodate the brush-holder yoke, which may be copied from any of the standard makes. Only two sets of brushes are required, each set comprising two carbon brushes ⅜ in. thick and 1⅛ ins. wide; the two sets must touch the commutator exactly 90° (11¾ segments) apart, center to center. The commutator must have 47 segments, and must measure 3 ins. along the shaft, extreme length. The commutator core must be bored to fit the portion, *c*, of the shaft, and key-seated to correspond. The diameter of the barrel should be not less than 4 ins., and the diameter measured at the connecting lugs must not exceed 6½ ins. The brush surface, measured

parallel with the shaft, must be $2\frac{1}{2}$ ins. long. It will be best to buy the commutator complete from one of the several makers of this class of apparatus.

Fig. 94 is the armature shaft. The key-seats are all $\frac{3}{8}$ wide and 3-16 deep. The dimensions of the shaft are below:

	At				Total
	f	a	c	j	Length
Diameter, inches	1	$1\frac{1}{4}$	$1\frac{1}{8}$	1	
Length, inches	$6\frac{7}{11}$	$6\frac{3}{16}$	$5\frac{7}{16}$	$3\frac{5}{16}$	$21\frac{3}{8}$

The field-magnet coils may be wound directly on the cores or on bobbins made of thin vulcanized fiber. If they are wound directly on the cores, the latter must be wrapped first with three layers of unbleached cottons and painted with shellac varnish, two circular coil heads of hard fiber being first fitted to the large part of each core. The coils consist of No. 22 single-cotton-covered wire, wound to a depth of $\frac{3}{4}$ in., exactly. The exact number of turns is immaterial, except that all four coils must contain the same number of turns, and as many turns should be put on as can be got in the space available. With careful winding, the builder should get 2,565 turns in each coil. For a 230-volt motor use No. 25 single-cotton-covered wire, and for 500 volts use No. 28 *double*-cotton-covered, wound to the depth specified. Should the reader prefer to wind the coils in bobbins, the magnet core need not be wrapped, of course. After each coil is completed, secure the outer end and cover the outside layer with unbleached cottons two layers deep, heavily varnished. Fig. 95 indicates how the field coils should be connected up.

FIG. 94

The armature coils of the 115-volt machine are of No. 13 double-cotton-covered wire, each coil containing 8 turns. The winding must be 2 wires wide and 4 layers deep per coil, so that when the coils are in place there will be 16 wires in each slot — 2 wide and 8 deep, as shown in Fig. 96. There are 47 coils, connected up wave-fashion. In winding the coils it will be advisable to bend a hook in each starting end and leave the final ends straight. The armature coils must be wound in a former so that the outline of the opening through each coil is a square measuring $4\frac{3}{4}$ ins. on each side. The ends should lead out from two corners, and each coil must be wrapped carefully and firmly with

two layers of German linen tape, each layer being painted with shellac varnish. The slots in the armature core should be provided with insulating troughs of press board 1-64 in. thick.

Put the coils on the armature all the same way — bent ends to the left and straight ends to the right, facing the commutator. There must be twelve teeth between the two slots in which any given coil is placed, and there must be 22 commutator segments between the two to which the terminals of any given coil are connected, as indicated by Fig. 97. It will be found best to first put on 12 coils in regular right-handed rotation,

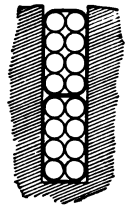


FIG. 96

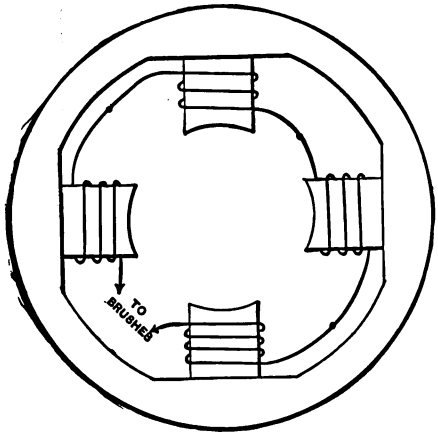


FIG. 95

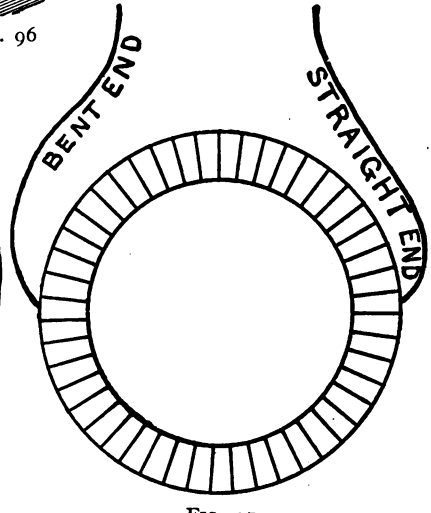


FIG. 97

pressing the ends down closely where they lap, and slipping a bit of thin oiled paper between the crossings. This will put one layer of coils in 24 of the slots. Then put coils in the 23 vacant slots in the same fashion; there will then be 46 half filled slots and one filled.

Continue the second layer of coils right along from the 24th coil, following the same plan as before. At the finish there will be a bent end and a straight end projecting from each slot. Carry the bent ends 11 or 12 segments to the left, around the commutator, and put them all in the segment slots. Then take any one of the straight ends, find the bent end

which is the other terminal of its coil, and connect the straight end, as shown in Fig. 97, with 22 segments between it and its mate. The other straight ends may be put in in regular order without tracing, if the coils have been put on the core properly and the bent ends in the commutator lugs in strict sequence.

If it is desired to build the machine for 230 volts, wind the armature with No. 16 double-cotton-covered wire, putting 15 turns in each coil — 3 wide and 5 deep — so that each slot will contain 30 wires, 3 wide and 10 deep. For 500 volts, use No. 19 wire, putting 28 turns in each coil — 4 wide and 7 deep — so that each slot will contain 56 wires, 4 wide and 14 deep. The principal technical data for the 115-volt machine are given below:

Revolutions per minute	1,320
Armature resistance, warm	0.4 ohm
Armature current, normal	22
Armature and brush drop, volts about	9
Per cent regulation about	8%
Flux density in air-gap	30,000
Flux density in magnet cores	93,000
Flux density in magnet yoke	48,000
Leakage coefficient	1.3
Resistance of field winding, ohms	169
Exciting current, amperes	0.68
Approximate efficiency, allowing 5 per cent for friction and windage	80%

The starting box should be purchased from any of the standard rheostat builders; a satisfactory home-made one of this size is rarely produced.

CHAPTER X

DIRECT-CURRENT 110-VOLT FAN MOTOR

THE construction of the direct-current fan motor described in this chapter is easily within the ability of any one at all experienced in the use

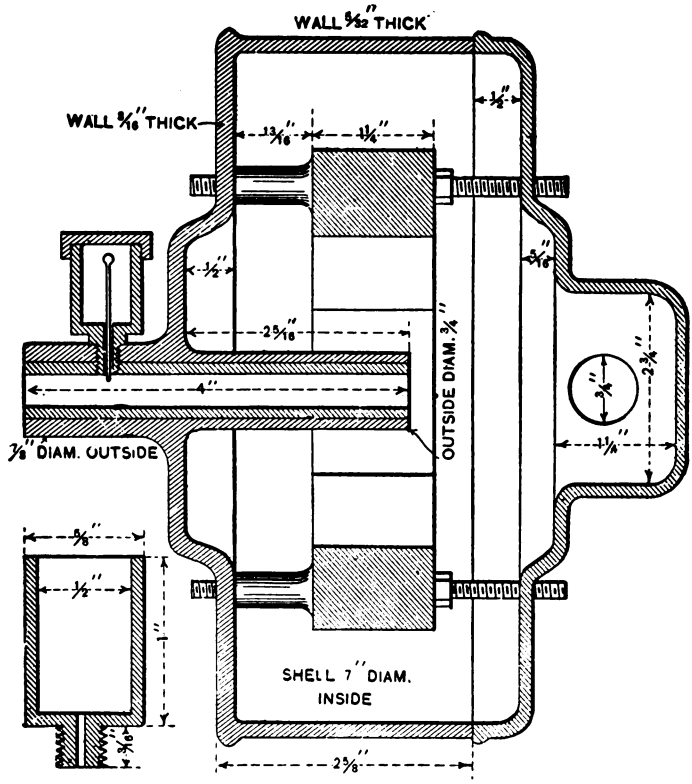


FIG. 99 FIG. 98

of machine tools. The motor is of the bipolar iron-clad type; the field magnet having the form and dimensions shown by Fig. 102. Fig. 98 is

an axial cross-section of the motor frame taken vertically. It is intended that the magnet proper shall be of cast steel set into a thin cast-iron shell, the front cap of which is integral with the shell, as indicated by Fig. 98; but if the builder should prefer, the entire structure may be made a single casting of steel. The first construction requires somewhat more machining, as it will be necessary to turn up the exterior of the field magnet and bore out the cast-iron shell so that the two will fit snugly together; but the result will be a very much better looking machine than if the field-magnet structure were wholly of cast steel. There is only a single bearing, the shell of which is cast integral with the motor casing, as indicated in Fig. 98, and this is provided with a grease cup of the ordinary gravity-feeding

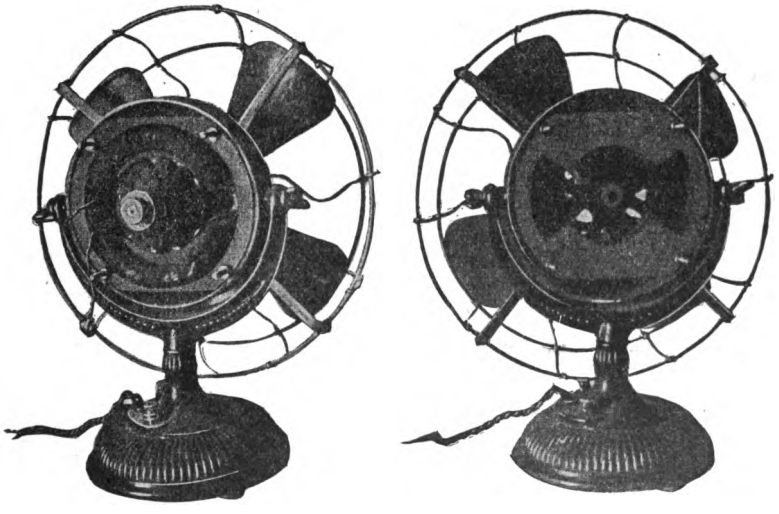


FIG. 100

type. A cross-section of the cup is included in Fig. 98, and a dimensioned drawing of it is given by Fig. 99.

The rear cap of the motor case, a sectional elevation of which is shown in Fig. 98, is detachable, and is provided with a recess extension near the center to accommodate the commutator. The brush-holders, which are of the ordinary tubular type, are mounted in insulating bushings in opposite sides of this extension. This end cap is intended to be of cast iron no matter which way the field magnet is constructed. It is secured in place by means of nuts which thread on four machine screws that pass completely through the field magnet. These four screws also serve to secure the fan guard to the opposite side of the case, and in the event that the field magnet proper is made of cast steel and the case of

cast iron, the same screws serve to hold the magnet in the case, as indicated in Fig. 98 and Fig. 100, which show this construction. The photograph shows the field-magnet casing mounted on a trunnion pedestal, but of

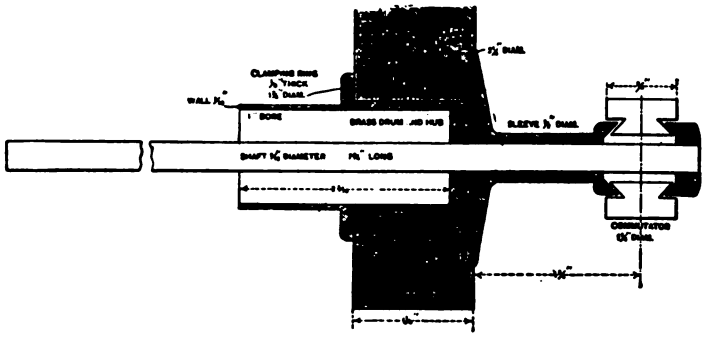


FIG. 101

course the builder can use any form of mounting he may prefer. This is about as simple, however, as any that an amateur can construct that will provide both vertical and horizontal adjustment. The trunnion yoke,

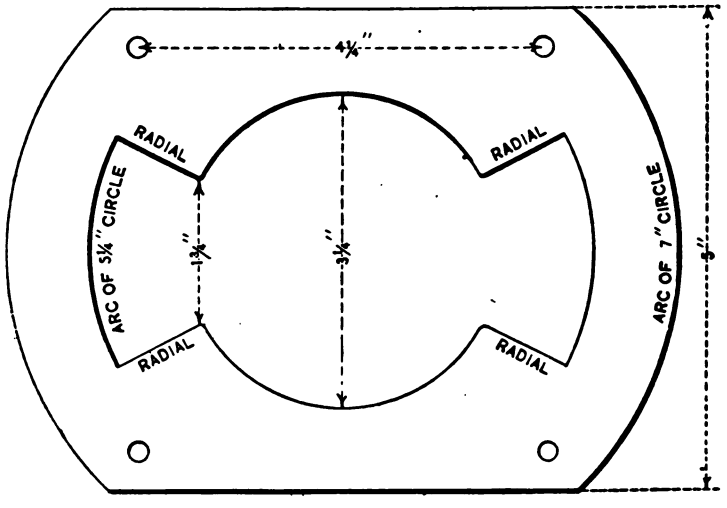


FIG. 102

shown in Fig. 100, is a separate casting with a stem fitting into a hole in the pedestal, which enables the motor to be swung around about a vertical axis, while the trunnions provide for adjustment up and down about a horizontal axis.

The armature core is of the ordinary drum type provided with 12 holes for the winding, the holes being located so that the outer edges are 1-16 in. below the edge of the armature core, as indicated in Fig. 104, which shows the condition of an armature disc before the core is assembled. After assembling the discs on the shaft the thin webs between the winding holes and the periphery of the disc must be cut away, preferably with a milling tool, but allowably with a hack-saw and file, leaving the discs as indicated by Fig. 105. The holes for the winding are $\frac{3}{8}$ in. in diameter. Fig. 101 is a cross-section of the complete core with the shaft and commutator. The brass drum on which the core discs are mounted is open at the end opposite from the commutator to allow the bearing shell on the motor frame to project into the core. There is no bearing beyond the commutator. Fig. 103 is a cross-section of the brush-holder with its insulating bushing.

The armature winding consists of 12 coils of No. 33 double-silk-covered magnet wire, each coil containing 185 turns. A winding diagram may

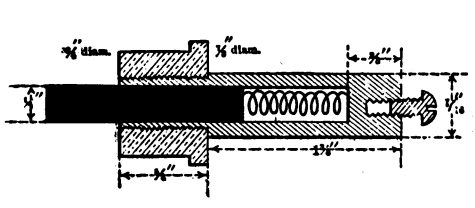


FIG. 103

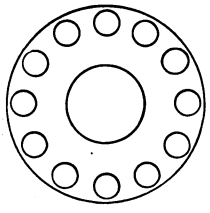


FIG. 104

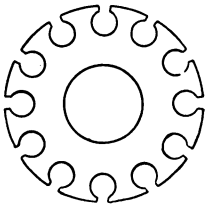


FIG. 105

be made by drawing an armature disc and numbering the slots successively. The winding should proceed as follows: First wind a coil in slots 1 and 6, twisting the terminals together lightly near slot 1. Then turn the armature core through half a revolution and wind a coil in slots 7 and 12, twisting the terminals together near slot 7. The next two coils should preferably come in slots 9 and 2, and 3 and 8; the next two in slots 5 and 10, and 11 and 4. This will complete half the armature winding. The seventh coil goes in slots 10 and 5 on top of the coil previously wound in those slots, but the terminals are twisted together at the opposite side of the coil near slot 10. The eighth coil goes in slots 4 and 11; the ninth coil goes in slots 2 and 9; the tenth coil goes in slots 8 and 3; the eleventh coil goes in slots 12 and 7, and the twelfth coil goes in slots 6 and 1. The coil terminals in each case should be twisted together near the first-named slot of each pair.

In winding the coils, care should be taken to preserve identification of the starting and finishing terminals of each coil. The best plan is to tie a knot in the starting terminals and then leave the finishing terminals

straight. When all the coils are in place untwist the 12 pairs of terminals and connect the coils together as follows: Twist the finishing end from slot 1 to the starting end from slot 2; finishing end from slot 2 to starting end from slot 3, and so on all the way around the armature. Then carry the twisted terminals out to the commutator, the pair from slots 1 and 2 going to segment No. 1, and the pair from slots 2 and 3 going to segment No. 2, and the pair from slots 3 and 4 going to segment No. 3, and so on all the way around. The terminals of the coils cannot be pulled through straight out to the commutator but must be laid flat along the head of the armature winding and bound into place by means of strings as illustrated in Fig. 107, which was made from the photograph of the complete armature. This precaution is necessary in order to prevent the edge of the recess in the removable cap from chafing the leads running to the commutator.

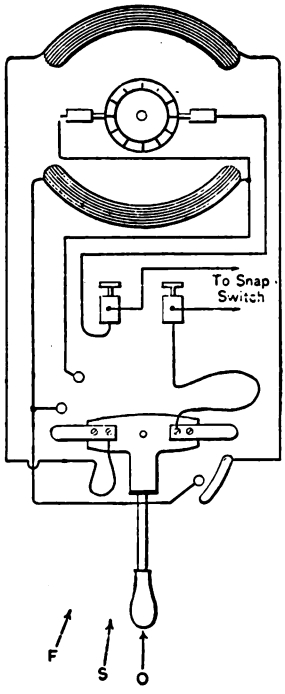


FIG. 106

The commutator has 12 segments, and is preferably of the construction illustrated in Fig. 101, but the reader is strongly advised to purchase a commutator from any one of the various manufacturers rather than to attempt to construct it. The winding of the armature across the heads must be compressed until it measures not more than $2\frac{3}{4}$ ins. along the shaft. The field-magnet winding consists of two coils of No. 25 single-cotton-covered magnet wire wound into the ordinary rectangular outline and then taped and bent to the form shown in Fig. 108. Each coil must

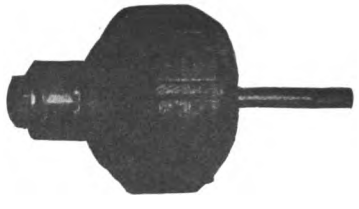


FIG. 107

FIG. 108

contain 30 layers of wire and each layer must have 44 turns, making 1320 turns per coil.

The machine is designed for two speeds and for 110-volt direct-current

supply. With the field-magnet coils connected in parallel it will run at the maximum speed, and with the coils connected in series it will run at the lower speed. The magnet coils are connected in series with the armature irrespective of their relation with each other. A switch should be provided in the base of the motor for the purpose of cutting the fan in and out of circuit, and changing the relation between the field coil connections. A diagram of the switch is shown by Fig. 106. The details of its construction may be worked out to suit the individual ideas of the builder, the only essential features being that it shall be mounted on a non-combustible base, preferably of slate or porcelain, with the metal parts so disposed that they cannot possibly come in contact with the pedestal base. The connections between the field-magnet coils and the switch in the base are preferably established by means of ordinary lamp cords led through holes in the end cap and in the pedestal base. Each of these holes should be insulated with a substantial fiber bushing. A double-pole snap switch should be inserted between the motor and the supply circuit.

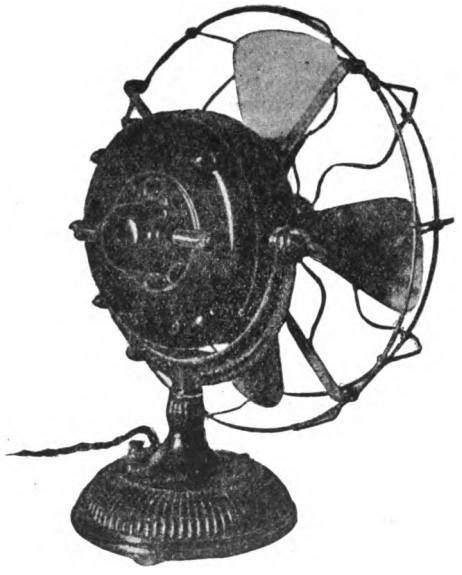


FIG. 109

Fig. 109 shows the complete motor with the fan and guard, but the reader is advised to purchase both fan and guard from any dealer in electrical supplies; the design of a propeller fan is not a sufficiently simple matter to justify an amateur in attempting it, and the same is true of the fan guard, although to a lesser degree. The motor should drive a 12-in. four-blade fan at 1600 revolutions per minute, if supplied with direct current at 110 volts potential.

CHAPTER XI

THREE HORSE-POWER LAUNCH MOTOR

THE engravings in this chapter show the salient features of a 3-horse-power multipolar motor designed particularly for driving the screw propeller of a small pleasure boat, say 14 to 16 ft. long. The motor is intended to take about 60 amperes at full load and to run at full speed, with full load, when supplied with 40 volts at its terminals. This means that 20

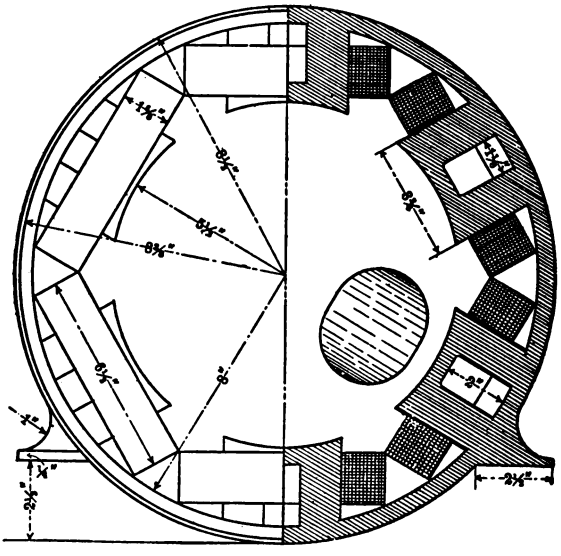


FIG. 110

cells of storage battery are required. Speed control is to be effected by grouping the battery cells for different voltages.

The field-magnet structure, which is shown by Fig. 110, is of cast steel, with six radial poles, the cross-section of each of which is of the shape and dimensions shown by Fig. 112. The poles have slots cored in them

in the process of casting, $1\frac{3}{4}$ ins. wide, and extending from within $\frac{1}{2}$ in. of the pole face clear back to the circle of the yoke ring, and passing, of course, clear through the poles axially. The object in coring out these slots is mainly to reduce the weight of the machine, although an incidental advantage in the distribution of magnetic flux in the air-gap also results. The yoke ring is of the short barrel type, the contour of its cross-section being perfectly rectangular, as indicated in Fig. 111. The edges of the yoke ring must be trued up at the same time that the pole faces are bored out, and a shallow recess turned up on the outside of the yoke for a distance of $\frac{1}{4}$ in. from each edge, as shown in Fig. 111. The object of this is to provide a seat for each of the end caps perfectly concentric with the bore of the pole faces. The motor rests on two bracket feet cast integral with the yoke ring, as indicated in Fig. 110. In mounting the machine in a boat it is contemplated that these brackets will rest on small wooden sills parallel with the shaft of the machine, and bolted to the framing of the boat.

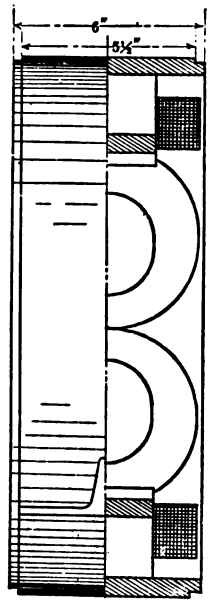


FIG. 111

The armature core, core drum and shaft are illustrated by Fig. 113, which is almost self-explanatory. The core drum, *d*, is of cast iron, with a hub and head at one end, and the armature discs, *a*, are clamped in place by a clamping plate, *c*, at the other end, similar to the head of the core drum. The clamping plate is drawn into place by means of four bolts extending through it and tapping into the head of the core drum. It is centered by a circular rib fitting into a recess in the interior of the open end of the drum. Both the core drum head and the clamping plate carry circular projections or barrels, *b b*, for the purpose of supporting the armature winding, which is of the straight-out type. The armature discs should be keyed to the core drum, a very small key sufficing for this purpose, as the discs must be very tightly compressed by the clamping ring, and this will transmit considerable torque from them to the shaft. The hub of the armature core drum must, of course, be keyed to the shaft, and it is preferable to also key the hub of the clamping plate, *c*, to the shaft, in order to avoid any twisting stress in the body of the core drum. The armature discs must have 46 slots 11-32 in. wide and 1 1-16 ins. deep, the slots being simply rectangular, as shown

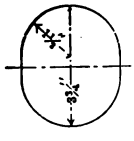


FIG. 112

in Fig. 116, which is a cross-section of a single slot and the wires within it.

The armature core discs are 10 13-16 ins. in diameter, and the hole through the center is $6\frac{1}{8}$ ins. in diameter. The length of the armature core parallel with the shaft when compressed into permanent shape must be precisely $3\frac{1}{4}$ ins. The outer diameter of the drum must, of course, fit the central hole of the armature disc, and its length, parallel with the shaft, is $3\frac{1}{4}$ ins. The inner diameter of the drum is $5\frac{1}{4}$ ins. The maximum diameter of the coil-supporting barrels, *b b*, is $8\frac{5}{8}$ ins., this diameter being next to the core discs. The diameter of the barrels at their outer edges is $8\frac{3}{8}$ ins., and their face measurement, parallel to the shaft, is 2 ins. The thickness of the clamping plate, *c*, is $\frac{3}{8}$ in., and the thickness of the drum head is the same. The thickness of the coil-supporting barrels, *b b*, tapers

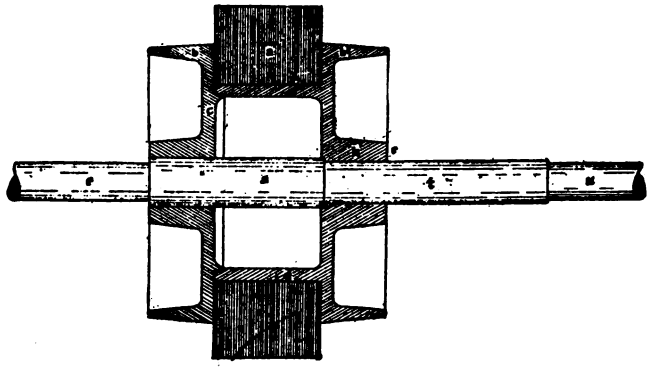


FIG. 113

from $\frac{1}{2}$ in. maximum to $\frac{1}{8}$ in. at the edges. The hubs of both the core drum and the clamping plate taper from 3 ins. to $2\frac{1}{2}$ ins. in diameter, and are 2 ins. in length measured clear through. The bore of the hub, *h*, is $1\frac{1}{4}$ ins., and it is counterbored to a depth of $\frac{1}{8}$ in. and a diameter of $1\frac{1}{2}$ ins. The object of this counterbore is merely to have a true face for the shoulder of the shaft to butt against without involving the work of machining the entire inner surface of the drum head. The clamping plate, *c*, it will be noticed, is provided with a projecting ridge fitting into a counterbore or recess in the open end of the drum. This ridge need not be more than $\frac{1}{4}$ in. deep, its function being merely to center the clamping plate. The dimensions of the various parts of the shaft are as follows:

	r	s	t	u
Diameter, ins.	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$
Length, ins.	7	$5\frac{3}{8}$	$6\frac{7}{8}$	4

The shaft is intended to be coupled to the propeller shaft by means of a plain flange coupling.

The journal boxes are cast integral with the enclosing caps of the field magnet. Figs. 114 and 115 are face views and cross-sections of these caps. It will be noticed that one of the enclosing caps has a circular extension chamber in the center; this is for the accommodation of the commutator and brushes. The journals are self-oiling, but of the wick-feed type in preference to the usual oil ring or roller form of feed. The wick feed is suggested for the reason that the pitching or rolling of the boat is likely to interfere with the operation of an oil ring by jamming it.

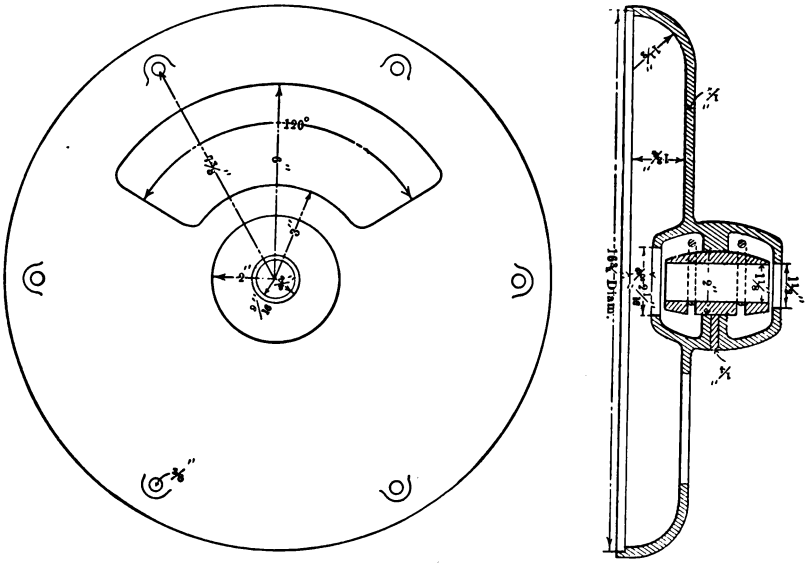


FIG. 114

The commutator is not shown, it being considered inadvisable for an amateur to attempt the construction of this most vulnerable part of the machine. A finished commutator can be bought from any one of the various manufacturers for less money than it would actually cost an amateur to build one, and there is no comparison between the results. There must be 46 segments, and the commutator barrel must be 6 ins. in diameter, with an available brush tread or face $3\frac{1}{2}$ ins. wide, measured parallel with the shaft. The total length of the commutator parallel with the shaft must not exceed 5 ins. The connecting lugs must be of such length as to give a diameter of $10\frac{3}{4}$ ins., measured from tip to tip of diametrically opposite lugs.

The machine is designed for the use of two sets of carbon brushes,

two brushes per set; each brush must be $\frac{3}{4}$ in. thick by $1\frac{1}{2}$ ins. wide, so that the total contact surface at each set of brushes will be $2\frac{1}{4}$ sq. ins. The builder can use his own judgment as to the type of brush-holder to be used, but should remember that it is absolutely necessary to have a reliable contact of low resistance between each brush and its holder. The author recommends the well-known Baylis reaction holder and brush. The two sets of brushes should be mounted precisely 60° apart. An opening is cored in the upper wall of the commutator chamber, through which access to the brushes may be had without removing the end cap; this opening

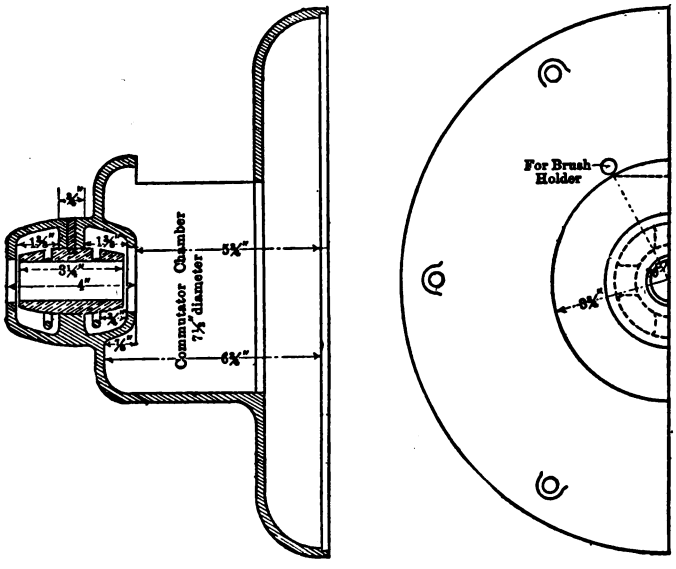


FIG. 115

may be normally closed by a cover conforming to the circular outline of the chamber.

The armature winding of the machine is of the two-path type, and comprises 46 coils of No. 11 double-cotton-covered magnet wire, wound two strands in parallel, with four turns per coil. The two strands in parallel should be wound side by side, so that a cross-section of the finished coil will show two wires in width and four in depth, as indicated in Fig. 116, which shows one of the armature slots with two half coils. The coils should be wound around two $\frac{3}{8}$-in. pegs, located 9 3-16 ins. apart, as indicated in Fig. 117, which is a side view of a coil wound on the pegs, ready to be formed. The illustration shows only one wire, as the two wires are side by side. The convolutions of the coils should be secured with fine

linen thread at each of the bends, *A* and *D*, and also at the two points indicated by the lines *B* and *C*. The distance from *A* to *B*, and from *C* to *D*, is 3 1-32 ins., the distance from *B* to *C* being $3\frac{3}{4}$ ins. Then the bends of the coil should be clamped from the points *A* and *D*, outward, leaving the two stretches of wire unclamped inside of the centers of the bend. Then each stretch or side of the coil should be held in a clamp, with long jaws, extending from *B* to *C*, one clamp being applied to the upper stretch and one to the lower stretch of wires, and the two sides should be pulled in opposite directions until a plan view of the coil resembles Fig. 118. Then it should be carefully covered with one wrapping of German linen tape, each layer being wound with a half lap, so that there will be two thicknesses of tape over the wires. Varnish the tape thoroughly and bake the coil until it is entirely dry.

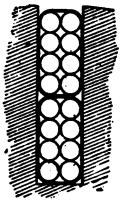


FIG. 116

The coils must be assembled on the armature core so that there will be 8 teeth between each side, *E* and *F*, Fig. 118. The coils must be put on the core with one side of each coil in its slot and the other side held temporarily above the core, successive coils being slipped under those already in slots until one side of every coil is in its slot and each coil is resting on the armature core on the other side. Then the other sides can be entered in the proper slots. When the coils are all in place in the slots they should be secured temporarily by two retaining bands of twine wrapped around the core under each end. Then the terminals should be carried to the commutator, all of the under terminals being put in first. The left-hand terminal of each coil should be carried to the left and the right-hand terminal to the right, as near equal distances as possible, the two terminals entering commutator segments between which there must be 14 other commutator segments; this is true of every armature coil.

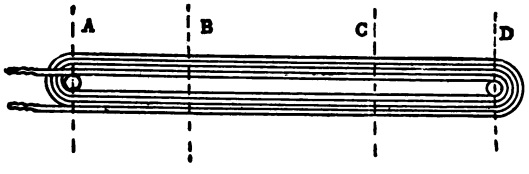


FIG. 117

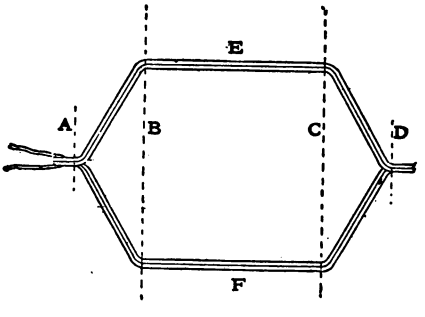


FIG. 118

After the ends have been soldered in, a binding of No. 19 tinned-iron wire should be put around the center of the core, being wound on an insulating strip of vulcanized fiber 1-64 in. thick; another binding of either

strong cord or thin brass wire should be put around the projecting ends of the coils, about midway between the end of the armature core and the extreme end of the coil projections. These binding wires must also be wound on fiber strips 1-64 in. thick.

The field winding consists of No. 2 single-cotton-covered magnet wire, each coil containing 35 turns; there should be 5 layers, with 7 turns in each layer. The coil should be wound on a forming block, the cross-section of which must have the shape and dimensions shown by Fig. 119. After winding the coil on the forming block it should be tied at all four corners with linen thread, in order to hold the wires in place while the coil is being removed from the forming block and during the operation of taping. After removing the block the coil must be insulated with two wrappings of German linen tape wound with a half lap, exactly like the armature coils were covered, the exterior being heavily varnished after the taping is completed. After varnishing, the coil should be baked until it is thoroughly dry. The six field coils are connected up in series in the usual manner to give alternate north and south poles, and the entire field winding is connected in series with the armature, making the machine a simple series-wound motor; speed regulation being obtained by changing the connections of the batteries supplying current to the motor.

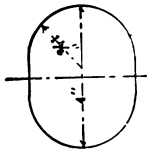


FIG. 119

CHAPTER XII

MULTIPOLAR THIRTY-FIVE-LIGHT INCANDESCENT DYNAMO

THE present machine is of the same general design as the 3-horse-power motor described in Chapter IX of this book. The field magnet consists of a cast-iron frame into which are set wrought-iron magnet cores having cast-iron pole-pieces, as shown in the semi-cross-section, Fig. 120. The cast-iron ring is preferably made in a single piece and the wrought-iron cores are turned to a very slight taper and drawn into holes in the yoke ring by means of a bolt and heavy washer from the outside. Unless the builder has excellent machine-shop facilities, however, and is an expert machinist, this construction will be found rather difficult, as it is necessary to have a perfect fit between the taper of the magnet core and that of the hole in which it is seated.

As an alternative the magnet frame can be cast in two pieces, the division being along the line *X*, Fig. 122. If the motor is built in this way, each half must be chucked and the joint faced off fairly smooth, although it is not necessary to have a perfect joint, as no magnetic lines of force pass across the joint. After truing up the abutting faces of each half of the magnet ring, the two halves should be clamped together with 1-32 in. of cardboard in between them and four straight holes bored for the reception of the field-magnet cores. A field-magnet core is shown by Fig. 121. The cast-iron pole-pieces must be accurately fitted to the ends of the cores and pinned permanently in place with iron pins.

The magnet ring and pole-pieces must be of the best grade of pig iron obtainable. The magnet cores should be made of Norway wrought iron. The corners of the pole-pieces should be heavily rounded so that no sharp edges are left. The length of the pole-pieces parallel with the shaft is the same as its width at right angles to this dimension. The outside diameter of the magnet ring is 20$\frac{3}{8}$ ins. The extreme breadth of the ring parallel with the shaft is 8 ins. The other dimensions are as follows:

	INCHES
Inner diameter of yoke ring	$17\frac{3}{8}$
A — Bore of armature chamber	8
B — Axial length of pole face	4
C — Width of pole-piece, tip to tip, in a straight line	4
D — Radius to which pedestal seat is cut	$8\frac{1}{2}$
E — Thickness of yoke ring	$1\frac{1}{2}$
F — Distance between ribs	7
G — Width of plane surface back of magnet coil	$6\frac{1}{8}$
H — Height, base line to armature center	12
O — Axial length of pedestal seat	4
P — Straight-line width of pedestal (width of pedestal seat is the same)	7
Q — Length of pedestal foot, commutator side	7

The dimensions of the magnet core (Fig. 3) are as follows:

	At		
	y	m	p
Diameter, inches	$3\frac{1}{16}$	$3\frac{3}{16}$	$3\frac{1}{16}$
Length, inches	.2	3	$1\frac{1}{4}$

Fig. 122 is an edge view of the field-magnet frame, including one journal pedestal shown in perspective, and the other in cross-section. After fitting the magnet cores into place in the ring, the pole-pieces should be bored and the pedestal seats cut, at one setting of the frame. Fig. 124 is a cross-section of the armature core, showing the details of construction. The discs are mounted on a cast-iron drum, which is provided with a flanged head and a hub, *J*, at one end, the other end being open. The discs are clamped in place by a cast-iron ring which is provided with a hub, *I*, and a flange, similar to those at the other end of the drum. The clamping ring is drawn to place by means of eight 3-16-in. bolts passing through holes in the clamping ring and tapping into the end of the cast-iron drum. The center lines of two of these bolts are indicated at *s*, *s*. The cast-iron drum must have a key-seat cut in it so that the discs may be positively driven.

Both the hub on the end of the drum and that on the clamping ring should be keyed to the shaft, so that there will be no liability to displacement. At each end of the core construction a disc of fiber 1-16 in. thick should be provided, as indicated by the heavy black lines in the engraving. These discs must be toothed exactly like the core discs, so that the ends of the magnetic core will be entirely covered. The iron core discs are $7\frac{3}{4}$ ins. in diameter, with a central hole 3 ins. in diameter, and 36 slots 9-32 in. wide by 1 1-16 ins. deep; the slots have parallel sides. The discs must be of the best grade of charcoal iron, 1-40 in. thick. The dimensions of the armature-core structure are as follows:

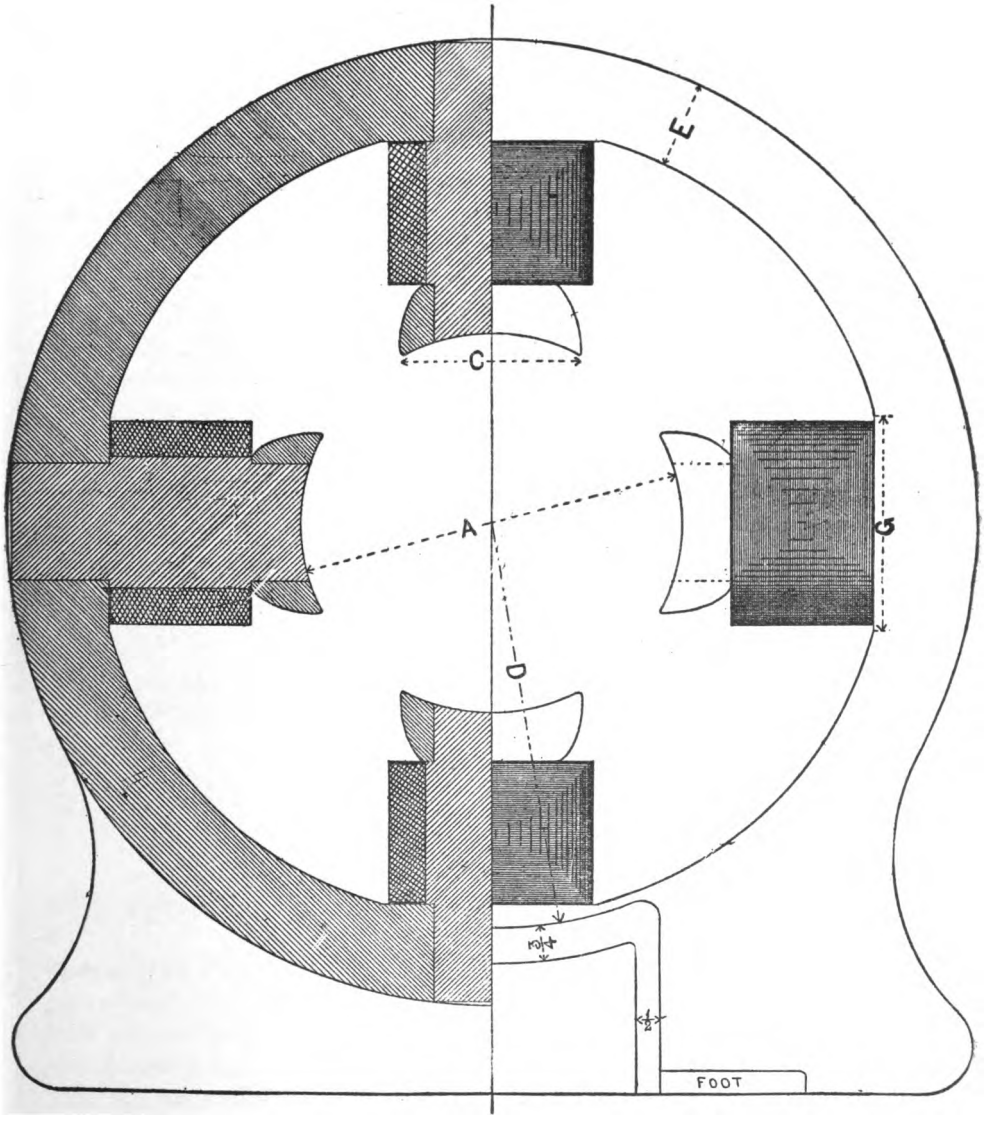


FIG. 120

	INCHES
I — Length of hub clear through (also length of flanges)	$1\frac{3}{4}$
Bore of this hub	$1\frac{1}{4}$
J — Length of hub clear through	$1\frac{13}{16}$
Bore of this hub	$1\frac{5}{8}$
K — Diameter of hubs	$2\frac{1}{4}$
L — Internal diameter of core drum	$2\frac{1}{4}$
M — Outer diameter of core drum	3
N — Diameter of flange and clamping ring	$5\frac{9}{16}$
Thickness of flange and clamping ring	$\frac{3}{8}$

The two journal pedestals are exactly alike and made of ordinary cast iron. The base must be turned accurately to conform to the circle to which the pedestal seat of the magnet frame is machined. The standard, or pedestal, is an open frame of $\frac{1}{2}$-in. metal; the box is of the ring-oiling type, with a single ring hung exactly midway of the journal. Fig. 123 is a transverse cross-section of the pedestal and box. The box is bushed; the bushing may consist of a brass casting turned to shape, or it may be made by babbitting a piece of thin brass tubing, the outer diameter of which is a snug fit in the box. The oil slot across the center of the box must be provided with a suitable covering to exclude dust. Each pedestal should be bolted to the magnet frame with two $\frac{3}{8}$-in. cap screws. The pedestal and box measurements are as below:

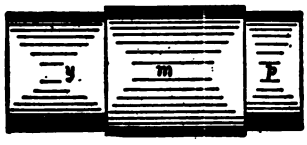


FIG. 121

	INCHES
P — Widest part of standard	7
R — Axial length of oil well	$2\frac{3}{4}$
S — Inner length of oil well	2
T — Inner width of oil well	3
t — Inner radius of oil-well bottom	$1\frac{1}{2}$
Q — Outside diameter of box	$2\frac{1}{4}$
V — Inside diameter of box	$1\frac{1}{2}$
W — Outside length of box	4
Y — Length of bushing	$3\frac{1}{4}$
Bore of bushing	1
Z — Projection of box beyond oil-well wall	$\frac{15}{16}$
Diameter of oil ring	$2\frac{1}{4}$
Bore of oil ring	$1\frac{7}{8}$
Width of oil ring	$\frac{3}{8}$

A bearing must be turned on the outside of the inner end of the pedestal on the commutator side of the machine, as indicated in Fig. 122, to accommodate the brush-holder rigging, which may be copied from any of the standard makes. Four carbon brushes are required, each brush $\frac{1}{4}$ in. thick and $1\frac{1}{2}$ ins. wide; the four must touch the commutator exactly 90° (18 segments) apart, center to center. The commutator must have 71 segments, and may measure 3 ins. along the shaft, extreme length. The commutator core must be bored to fit the portion, *c*, of the shaft, and key-seated to correspond. The diameter of the barrel should be not less

than 3 ins., nor more than 4 ins., and the diameter measured at the connecting lugs must not exceed 7 ins. The brush surface, measured parallel with the shaft, must be 2 ins. long. It will be best to buy the commutator complete from one of the several makers of this class of apparatus.

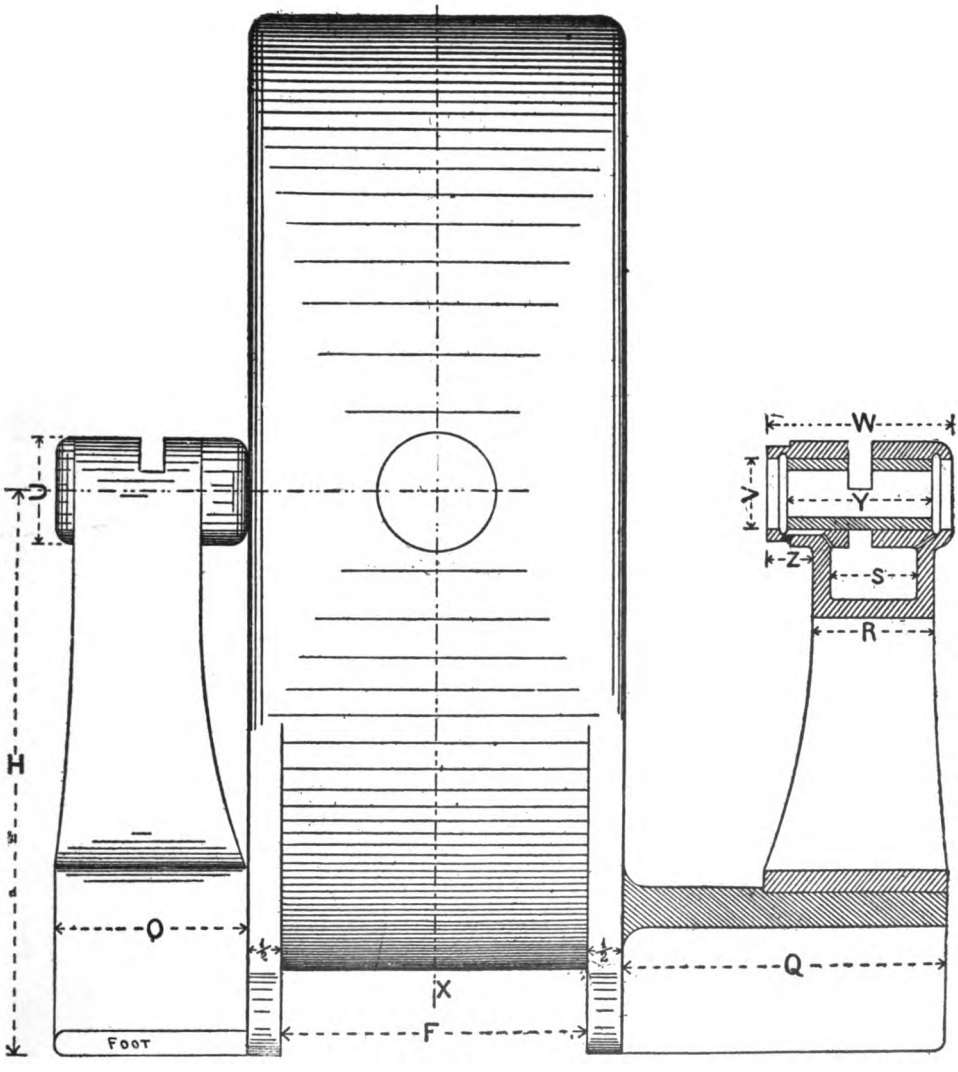


FIG. 122

Fig. 125 is the armature shaft. The key-seats are all $\frac{3}{8}$ in. wide and 3-16 in deep. The dimensions of the shaft are as follows:

	At				Total Length
	f	a	c	j	
Diameter, ins	1	$1\frac{1}{4}$	$1\frac{1}{8}$	1	
Length, ins	$6\frac{7}{16}$	$6\frac{1}{16}$	$5\frac{3}{16}$	$3\frac{5}{16}$	21

The field-magnet coils may be wound directly on the cores or on bobbins made of thin vulcanized fiber. If they are wound directly on the cores, the latter must be wrapped first with three layers of unbleached cottons and painted with insulating varnish, two circular coil heads of hard fiber being first fitted to the large part of each core. The coils consist of No. 18 single-cotton-covered wire, wound to a depth of $1\frac{3}{8}$ ins. exactly. The exact number of turns is immaterial, except that all four coils must contain the same number of turns, and as many turns should be put on as can be got in the space available. With careful winding the builder should get 30 layers in each coil, and 60 turns per layer, making 1800 turns per coil.

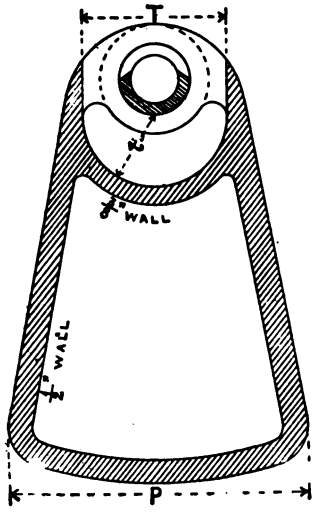


FIG. 123

Should the reader prefer to wind the coils in bobbins, the magnet core need not be wrapped, of course. After each coil is completed, secure the outer end and cover the outside layer with unbleached cottons two layers deep, heavily varnished. Fig. 126 indicates how the field coils should be connected up.

There are 71 armature coils, each consisting of six turns of No. 13 double-cotton-covered magnet wire. The coils are wound around two $\frac{1}{2}$-in. pegs set $10\frac{1}{2}$ ins. apart, center to center, all of the turns being wound on top of each other, none side by side. Fig. 127 shows one of the coils wound on the two pegs and ready for shaping. After completing the winding of each coil the wire should be temporarily secured by means of linen threads tied around the coil at each end and in the center of each reach of the coil. When all the coils are

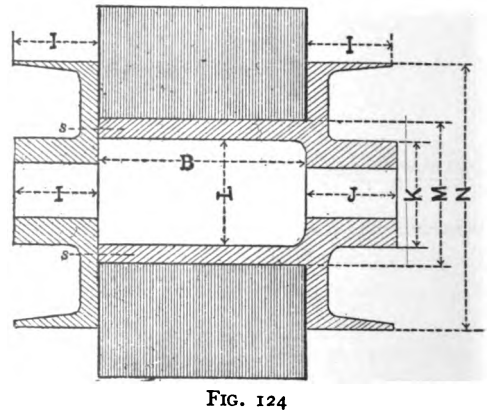


FIG. 124

wound they should be formed in pairs, two coils being placed side by side with strips of varnished fuller board 0.01 in. thick between them, as indicated by Fig. 128, and bent to the shape shown by Fig. 129. Before bending the coils to shape, the ends must be clamped from the points *A* and *D*

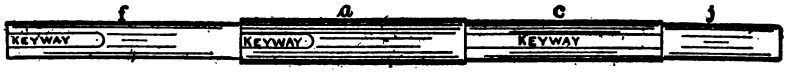


FIG. 125

outward and from the points *B* and *C* inward, so as to locate the bends accurately. The distance from *A* to *B* and from *C* to *D* is 3 ins., so that the distance from *B* to *C* will be $4\frac{1}{2}$ ins.

The straight reaches of the coils must be pulled apart far enough to enable the coil to go into two slots on the armature core between which there are eight teeth. Then each pair of coils should be carefully wrapped with one layer of German linen tape, wound with a half lap, so that there will be two thicknesses of the tape on each side of the coils. Varnish the outer surface of the tape thoroughly, then bake the coils at a temperature of 120 to 130 degrees until they are thoroughly dried. If the builder prefer, "linotape" or any other oiled tape may be used, and the varnishing thereby eliminated. When the coils are assembled properly on the core there will be two coils for each slot. It is for this reason that the coils are made up in pairs as described. They must be assembled on the core so that between the two sides of each pair of coils there will be eight core teeth.

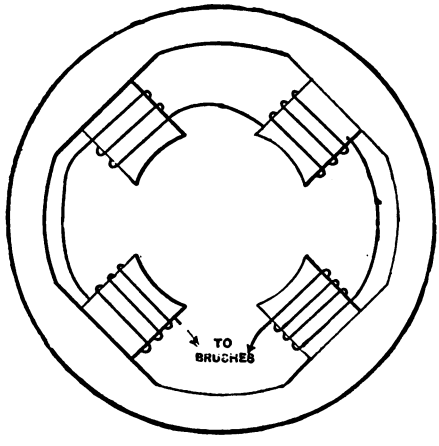


FIG. 126

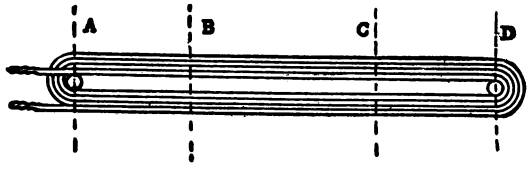


FIG. 127

When the coils are all in place they should be secured temporarily by two retaining bands of twine wrapped around the coils at each end just outside of the armature core. Then the terminals may be carried to the commutator lugs, all of the lower terminals being put in first. The terminals should be carried straight out to the com-

mutator and care must be taken that the coils are connected up in exactly the same fashion all the way around. The terminals of each coil are connected to two neighboring commutator segments. Having put all the lower terminals in place in proper rotation, the builder can start at any convenient point with the upper terminals, being sure that the first one

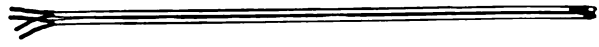


FIG. 128

goes in the commutator lug immediately alongside of the lug to which the other terminal of that coil has been connected. Having started properly, the terminals can be put in, one after the other, in the sequence in which they project from the armature slots, without further testing, provided the lower terminals have all been put in in proper sequence.

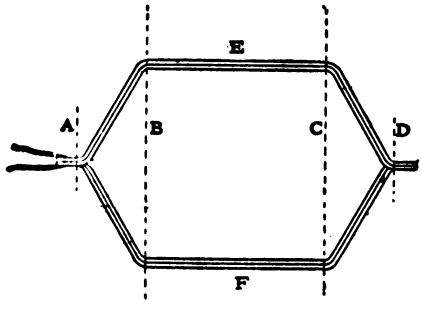


FIG. 129

After the armature terminals have been soldered to the commutator lugs, two bindings of No. 18 tinned-iron wire should be put on around the core, one binding about $\frac{1}{2}$ in. from each end of the core; each binding should be about 1 in. wide, measured parallel with the shaft. The coil projections which extend out beyond the armature core proper must be bound down to the barrels which support them by means of either No. 20 brass wire wound over two or three varnished layers of canvas or else heavy linen twine wound over a single layer of canvas. Only one binder will be necessary at each end of the armature winding. If there is an appreciable drop in the wiring between the dynamo and lamps, the speed should be increased until the voltage at the lamps is normal at full load, with all the rheostat cut out.

The principal data applying to the machine are as follows:

E.m.f. at the brushes at no load	115 volts
Armature speed	1400 r.p.m.
Resistance of armature winding, warm	$\frac{1}{2}$ ohm
Normal armature current	19$\frac{3}{4}$ amp.
Normal current delivered to external circuit	18 amp.
Normal exciting current in field winding	1$\frac{3}{4}$ amp.

The lamp rating of the machine (35 lamps) is based on the use of 3$\frac{1}{2}$-watt 16-candle-power lamps. With 3.1-watt lamps the machine will, of course, maintain a correspondingly greater number.

CHAPTER XIII

A SEVENTY-FIVE-LIGHT INCANDESCENT DYNAMO

THE dynamo forming the subject of this chapter is designed to maintain 75 16-candle-power incandescent lamps at 110–120 volts. The field magnet is of the familiar radial-pole type with circular yoke, and is provided with a partial "shrouding" on each side somewhat similar to the practice observed by the Crocker-Wheeler Company. The principal object of this shrouding is to give the machine a rather more finished appearance than it would have without it, and if any reader who may undertake to build the dynamo prefers to leave off this web it may be done without affecting the operation of the machine.

Fig. 130 is an end view of the field-magnet frame minus the coils and journal boxes. Fig. 131 is a plan view of the frame, which shows the arrangement of the projecting feet that support the journal pedestals, and Fig. 132 is a sectional view on a line through the center of the field-magnet structure. In order that the design may be available to a larger number of readers, cast iron has been adopted as the material for the field magnet instead of cast steel, which, of course, is the usual modern practice. The only machine work necessary on the field magnet is boring out the pole faces and tooling the seats for the journal pedestals, all of which must be done at one mounting of the magnet frame in order to insure accurate alignment between the armature chamber and the journals. Fig. 133 is a section of one magnet pole, and the corresponding part of the yoke, taken on the line *C–D* of Fig. 130 and Fig. 134, is a cross-section of a magnet core taken on the line *A–B* in Fig. 132.

The dimensions of the magnet which are not shown in the drawings are as follows:

	INCHES
Extreme diameter of shell	17
Extreme diameter over the ribs	18¼
Distance between ribs	9
Thickness of each rib parallel with shaft	1
Total plan length of field-magnet frame from outside to outside of journal pedestal seats	24½

Figs. 135 and 136 are sectional views of a journal box and pedestal, the former being an axial section and the latter a transverse section. The section of Fig. 135 is taken on the line *J–K* of Fig. 136, and the section of Fig. 136 is taken on the line *H–I* of Fig. 135. As the sketches plainly show, the bearing is of the oil-ring variety, with a circular reservoir, and the sleeve is perfectly straight, this type being much easier for an amateur to construct than a self-aligning bearing. If ordinary care is taken in

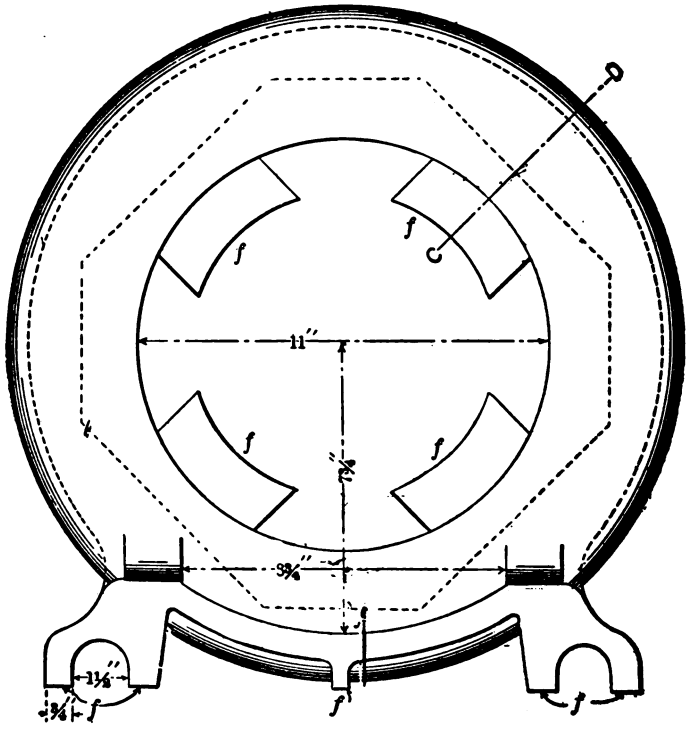


FIG. 130

cutting the seats of these pedestals and in turning off their bases, the bearings cannot fail to come in alignment without any special provision in the way of a swiveling bushing. The pedestals and journal boxes are of cast iron, of course, and the bushing may be made either of solid brass or of a thin seamless brass tube babbitted. On the inner end of one journal box a seat ½ in. long should be turned for the brush-holder yoke. Only two sets of brushes are required, and these must bear upon the commutator exactly one fourth of a circle apart. The brush yoke, therefore, may be of the V type in preference to the ordinary straight arm which is used on

bipolar machines. Returning to the bearings, the oil rings will be $2\frac{1}{2}$ ins. in diameter, inside, 5-16 in. wide parallel with the shaft, and $\frac{1}{8}$ in. thick, measured radially.

Fig. 137 shows the shaft and a sectional view of the armature core and supporting drum. This drum is a simple cylinder, *d*, 3 ins. in diameter outside when finished, and provided with a flange, *g*, at one end, which carries at its outer edge a drum or barrel, *b*. The function of this barrel is to support the projecting ends of the armature coils. The discs are mounted on the drum, *d*, and clamped in place by means of a ring, *r*, which carries a barrel, *b*, exactly like the one on the flange of the core drum. These flanges project $2\frac{1}{4}$ ins. from the core discs. The ring, *r*,

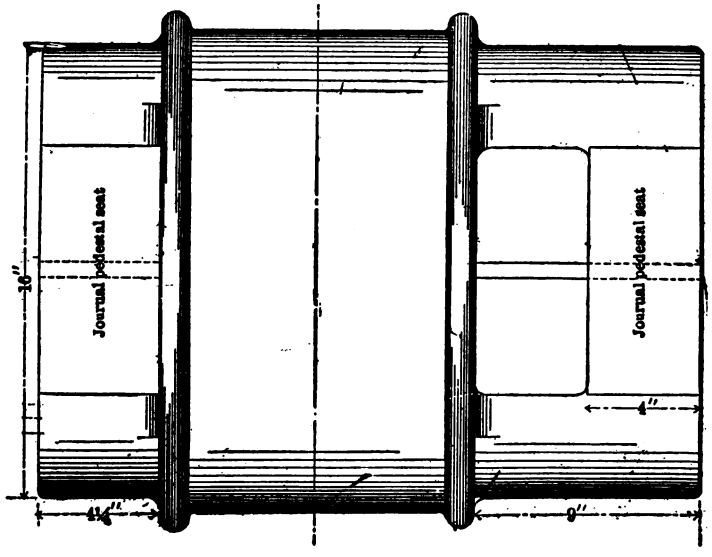


FIG. 131

may be secured to the drum, *d*, by means of six 3-16-in. machine screws. The dimensions of the different parts of the shaft are marked on the sketch, as well as the principal dimensions of the armature core and spider; those which are not indicated are as follows:

	INCHES
Diameter of armature discs	8
Number of slots	40
Size of each slot	$\frac{1}{4} \times 1\frac{5}{16}$
Diameter of extension barrels	$5\frac{3}{4}$
Diameter of core hubs, *h*	2
Extreme length of core drum from end to end of the hubs	$9\frac{1}{4}$
Diameter of core drums, *d*	3
Radial thickness of drum wall	$\frac{3}{8}$
Thickness of flange, *g*, and ring, *r*, parallel with shaft	$\frac{1}{2}$

The commutator should be purchased from some of the standard manufacturers. Its extreme length along the shaft must not be over $4\frac{1}{4}$ ins. It must have 79 segments, and should be not less than 5 ins. in diameter. The width of the brush tread parallel with the shaft must be not less than 3 ins., and the diameter from tip to tip of diametrically opposite connecting lugs must be $7\frac{1}{2}$ ins.

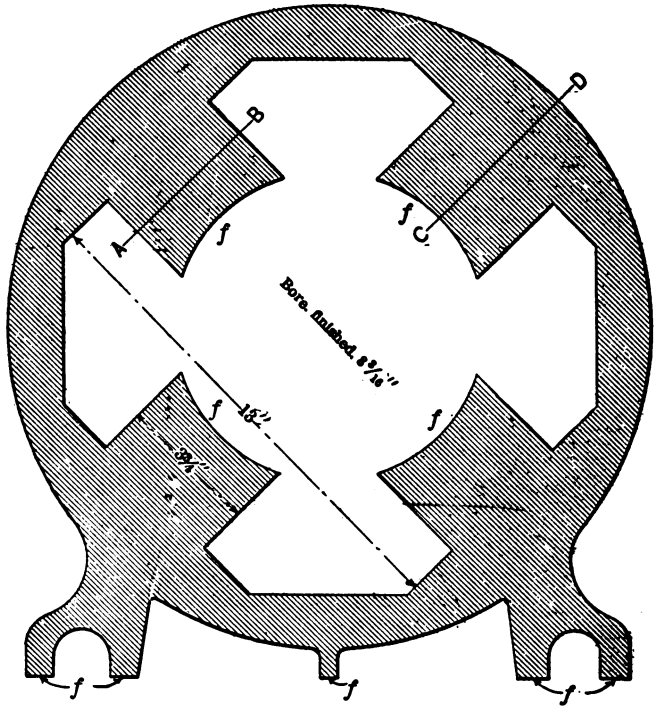


FIG. 132

The machine is designed for the use of carbon brushes, each set comprising two brushes $\frac{5}{8}$ x $1\frac{1}{4}$ ins. The builder can exercise his own judgment as to the type of brush-holder to be used, but should remember that it is indispensable to have a reliable contact of low resistance between the brush and the holder. As noted above, there are only two sets of brushes, these being set "on the quarter," or 90 degrees apart.

The field winding of the machine consists of four coils of No. 18 double-cotton-covered magnet wire wound 14 layers deep and 46 turns long parallel with the axis of the core, giving 644 turns per coil. If the builder is able to put more turns than this without exceeding a depth of 11-16 in., so much the better, but the coil should not be deeper than this. The coils

are connected up in the usual manner, so that the polarity of the magnet cores alternates, and a rheostat must be provided to regulate the field current. As in the case of the commutator, it is wholly inadvisable for an amateur to attempt the construction of his rheostat; consequently, no directions are given for this.

Each field coil must be taped with two layers of German linen tape

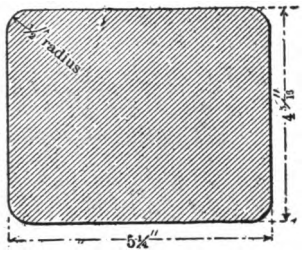


FIG. 133

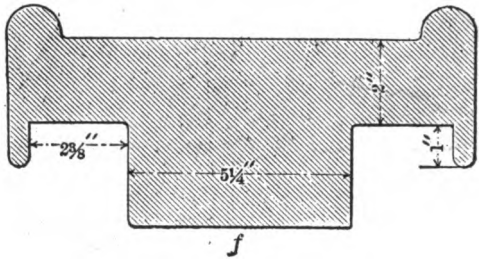


FIG. 134

wound through the coil shuttle-fashion, so that the tape crosses the wires at right angles. As in the case of the armature coils, each layer of taping

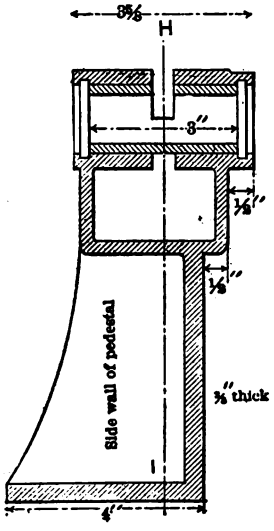


FIG. 135

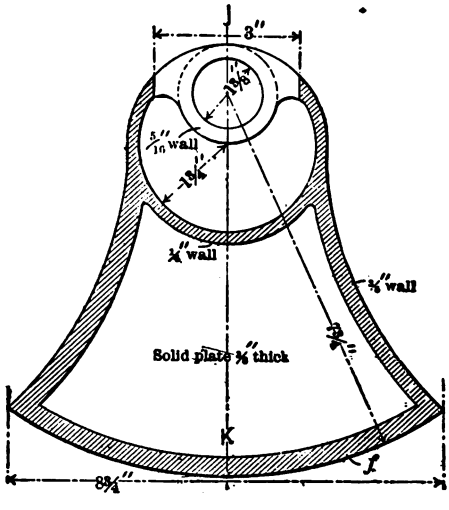


FIG. 136

must be wound with a half lap, varnished and thoroughly dried, *i.e.*, the first layer must be thoroughly dried before the second layer of tape is put on, and then the second layer must be varnished and dried similarly.

The armature winding consists of 79 coils of No. 8 double-cotton-

covered magnet wire, each coil containing 2 turns. The coils must be wound in pairs around two $\frac{3}{8}$-in. pegs, as indicated in Fig. 138, the four turns (two coils) being wound one on top of the other, so that when the pair of coils is finished it will present about the appearance indicated by

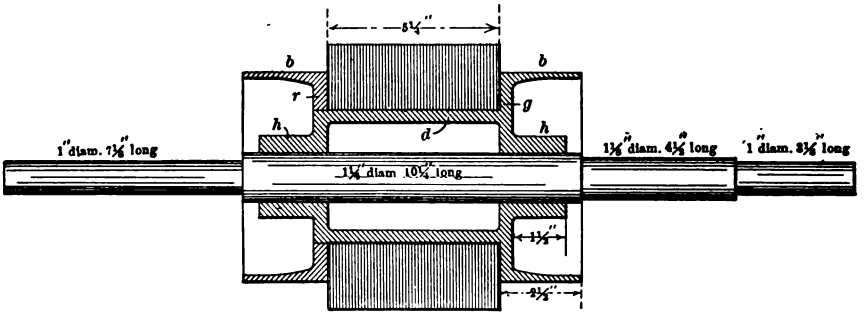


FIG. 137

the sketch. The convolutions of the coils should be secured with fine linen thread at the points indicated by the lines *B* and *C*, and also at the bends *A* and *D*. Then the bends of the coils should be clamped from the points *A* and *D* outward, and the two straight reaches or "sides" pulled apart until the plan view of the coils is as shown in Fig. 139. Then the wires should be wrapped with two layers of German linen tape, with half-lap, so that there will be four thicknesses of tape on the coils. Each layer of tape should be thoroughly varnished, and the completed coil baked until it is dry. If the builder prefers, he may use "linotape" instead of German linen, and omit the varnishing, as "linotape" is thoroughly impregnated with oil.

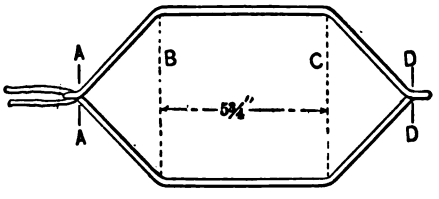


FIG. 138

The coils must be put in the core slots so that each pair embraces 9 teeth. It is imperative that all of the coils be wound exactly alike and put on the core alike, so that the starting ends of all of them will occupy the same relative positions when all are in place in the slots. When all the coils are in the slots, they should be temporarily secured with two bands of binding twine around the core at

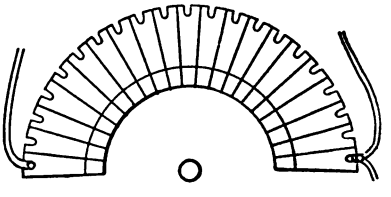


FIG. 139

each end. Then the coil terminals may be carried to the commutator, all of the under terminals being put in the lug grooves first and in regular sequence.

It will be found convenient to lead the under coil terminals to commutator segments which lie about 20 bars to one side of the bar opposite the bend of the coil, and the upper terminals will then go to the other side of the bend by about the same distance. Having put all of the under terminals in the commutator lugs, start at any convenient place to put the upper terminals in place; the first of these must go to the commutator segment which is 39 steps from the one to which the under terminal of the same coil is connected. In other words, the two terminals of each coil must be connected to two commutator bars between which there are 38 other bars.

After the coil leads have been soldered to the commutator lugs, a binding of No. 18 tinned-iron wire should be put around the center of the armature core, and another binding of No. 20 brass wire put around the projecting parts of the coils at each end of the core, near the end of the supporting barrel. All three bindings must be wound on fiber strips not less than 1-32 in. thick.

The rated speed of this machine is 1500 r.p.m., at which speed it should give 115 to 120 volts at no load, with no resistance in the field circuit. If it fails to do so, it will be on account of the quality of the material in the field magnet; in that event the speed must be increased to get the proper voltage. The armature will carry 44 amperes.

CHAPTER XIV

FOUR-HUNDRED-AMPERE ELECTROPLATING DYNAMO

THIS machine, so far as the field magnet and all mechanical details are concerned, is identical with the 75-light dynamo described in the preceding chapter. The only differences are in the parts and features described in this chapter.

The armature core has 32 slots, each 5-16 x 1 1-16 ins.

The commutator must be 5 ins. in diameter at the barrel and its face $2\frac{1}{2}$ ins. wide parallel with the shaft. The diameter over the lugs is the same as in the 75-light dynamo. It must have 32 segments.

The machine is designed for four sets of copper brushes, opposite sets being connected together, of course, as in the case of all multipolar machines. Each set comprises two brushes, each $\frac{3}{8}$ in. thick by 1 in. wide; the ends of the brushes must be beveled to such an angle as to give an actual contact surface $\frac{1}{2}$ in. by 1 in. The builder can use his own judgment as to the type of brush-holder, although there is not much latitude when it comes to designing a brush-holder for copper brushes. It will be advisable to copy the design of brush-holder used on some standard machine.

The field winding of the machine consists of four coils of No. 11 single-cotton-covered magnet wire wound 12 layers deep and 23 turns long parallel with the axis of the core, giving 276 turns per coil. If the builder is able to put more turns than this without exceeding a depth of 13-16 in., so much the better, and the coil should not be deeper than this. The coils are connected up in the usual manner, so that the polarity of the field-magnet cores alternates, and a rheostat must be provided to regulate the field current. As in the case of the commutator it is inadvisable for an amateur to attempt the construction of a rheostat, and for this reason no instructions are given for this work. The field rheostat must be able to carry 50 amperes continuously without overheating. Each field-magnet coil must be taped and varnished as described in the preceding chapter.

The armature winding consists of 32 coils of 1 turn each, and each consisting of two No. 4 wires in parallel. Fig. 140 shows one coil, which,

as the sketch shows, is merely a loop 14 ins. long from the free ends to the center of the pin around which the loop is bent. After bending the loop to shape it should be clamped across the bend at the line *D*, and each side clamped individually at the points indicated by the lines *C* and *B*; the bodies of the clamps here must be within the space between the two lines, so that the extreme outer edges of the clamp coincide with the lines *B* and *C*. Then the two sides should be bent apart until a plan view of the coil looks like Fig. 141. After it is in this shape it should be carefully taped with a single wrapping of German linen tape, wound with a half lap, so as to give two complete thicknesses of the tape. After taping, each coil should be varnished with shellac or some other reliable armature varnish and baked until it is thoroughly dry.

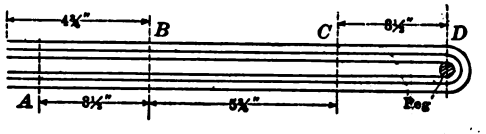


FIG. 140

The coils must be assembled on the armature core so that there will be 7 teeth between the two sides of each coil. When the coils are all in position on the armature core they should be temporarily secured in place by two retaining bands of twine wrapped around the coil projections at each end of the armature. Then the coil connections should be carried to the armature, all of the under terminals being put in place first and followed by the upper terminals. The two terminals of each coil must be connected to neighboring segments of the commutator. Having put all the lower terminals in the commutator segments, the builder can start at any convenient place with the upper ends, and after the upper end of the first coil is put in the segment next to the lower end of the coil, all of the other upper ends follow in regular rotation, so that it is not necessary to test each coil, provided the under ends have all been inserted in proper rotation and that the upper terminal of the first coil is properly located.

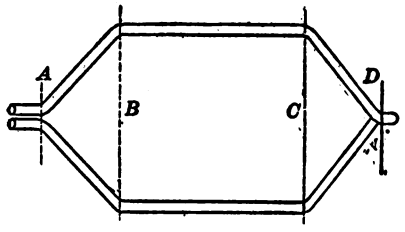


FIG. 141

CHAPTER XV

A ONE-HUNDRED-AMPERE ELECTROPLATING DYNAMO

THE accompanying engravings are reproductions made from working drawings for the construction of an electroplater having a capacity of approximately 100 amperes at 6 volts. Figs. 142 and 145 are assembly drawings of the machine, the latter being a complete axial section. The yoke ring is of cast iron, and it is intended that the magnet poles shall be made of round wrought iron of the size and shape indicated by Figs. 142 and 143, and cast-welded into the yoke ring. The pole-face curve shown at the right-hand end of the magnet core in Fig. 143 is intended to be machined before the poles are cast into the yoke; this may best be done by mounting the cast-iron pole-piece (Fig. 144) on the end of each of the poles, clamping the four poles in a jig and boring out the pole faces. Care must be taken that the distance from the left-hand end of the body of the magnet pole (Fig. 143) to the center of the pole face curve is exactly $3\frac{1}{4}$ ins., as marked on the drawing, and when the poles and shoes are set into the mold, prepatory to casting the yoke ring, extra care must be taken to see that the distance between diametrically opposite poles is $6\frac{1}{2}$ ins., as specified in Fig. 142. It will be found a good plan to bolt the four poles to a central cast-iron drum so as to secure the proper alignment when they are set into the yoke-ring mold.

Two journal-box bracket patterns will be necessary, since the bracket at the commutator end must be extended farther out from the yoke ring than the one at the pulley end of the machine. Fig. 146 is a face view of one of the bracket rings, both of which are identical from this view point. The journal-box housings are shown cast in a single piece with the pedestal bracket and having a thick web straight across the center horizontally, which is bored out to receive the bushing. This may be secured in place by means of a pin set into one side of the housing at a point midway between the oil-ring slot and the end of the web in which the bushing is seated. This arrangement is not shown, it being thought best to leave the exact details of the construction to the individual fancy of the builder. It makes

no difference, of course, what the details of the box construction are so long as the bore and length of the bushings are adhered to and a suitable projection is provided on the inner end of the right-hand housing in Fig. 145 to take the brush-holder quadrant. Fig. 147 shows the oil ring, which

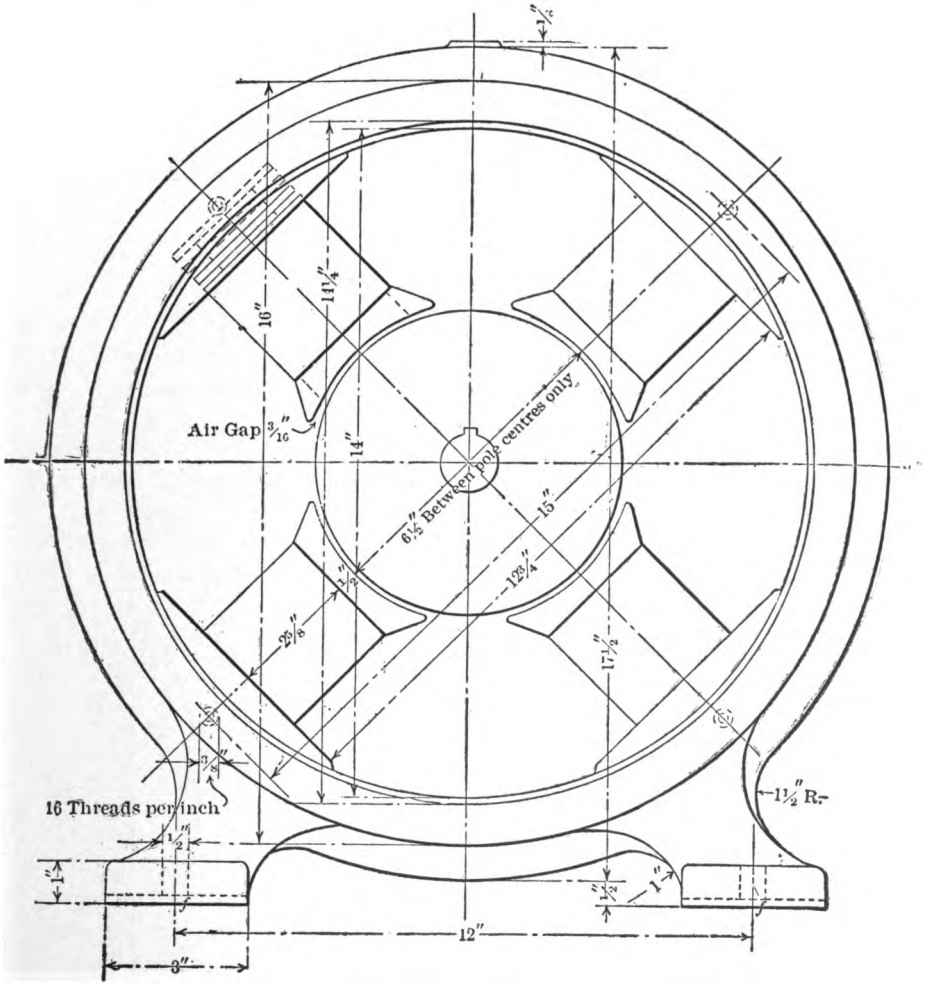


FIG. 142

should be made of a rather hard grade of brass. The shaft shown in Fig. 149 may be made of ordinary machine steel.

The armature is of the usual drum construction, and the discs should be cut from sheet iron not more than 25 mils thick. The discs must be

6¼ ins. in diameter and must have 41 slots, each 7-32 in. wide and ¾ in. deep, the sides of the slots being parallel with each other. The corners at the bottoms of the slots should be rounded to 1-16 in. radius in order to

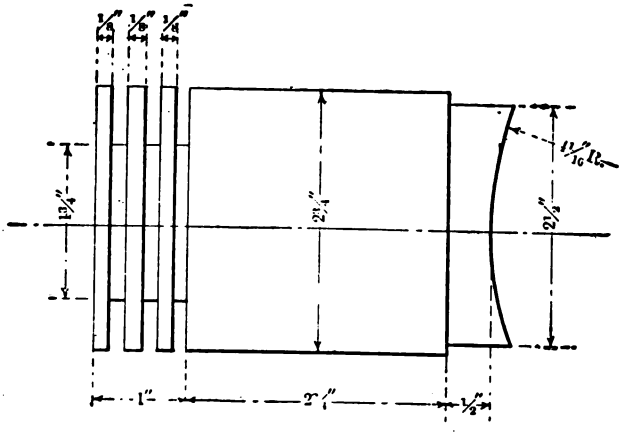


FIG. 143

strengthen the teeth and also to increase the width of the magnetic path in the tooth at that point. The discs must be key-seated, as indicated in Fig. 142, the key-seat being ⅛ in. deep and ¼ in. wide. The key is to be ¼ in. square and without any taper, of course. The discs are clamped on the shaft between two heads of the size and construction shown in Fig.

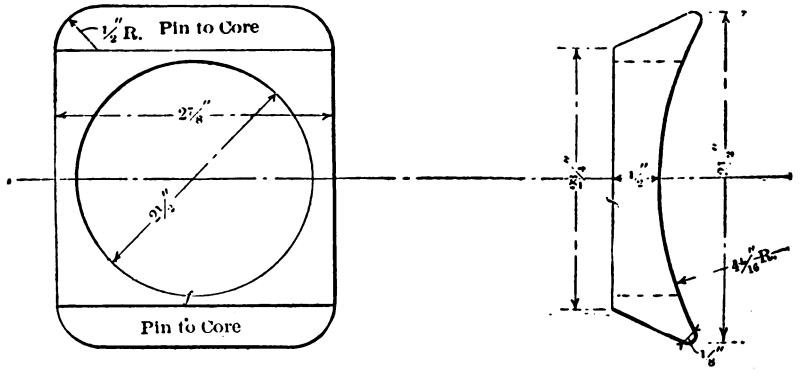


FIG. 144

149. These are cast-iron plates, each having a cylindrical flange extending axially from one side and being tapered on the outer face so as to form a slanted or tapered barrel for the support of the armature coils where they extend beyond the ends of the core.

As shown clearly in Fig. 145, the clamping head at the end of the armature toward the pulley backs up against the collar on the shaft, and the one at the end toward the commutator is kept in place by the round nut shown in Fig. 148. It will not be advisable to attempt to compress the discs by screwing up this nut; the proper number of discs (to make a 3-in. core when assembled under considerable pressure) should be slipped on the shaft and compressed by screw pressure applied to a stout plank or beam laid across the end of the armature structure and having a $3\frac{3}{4}$-in. hole

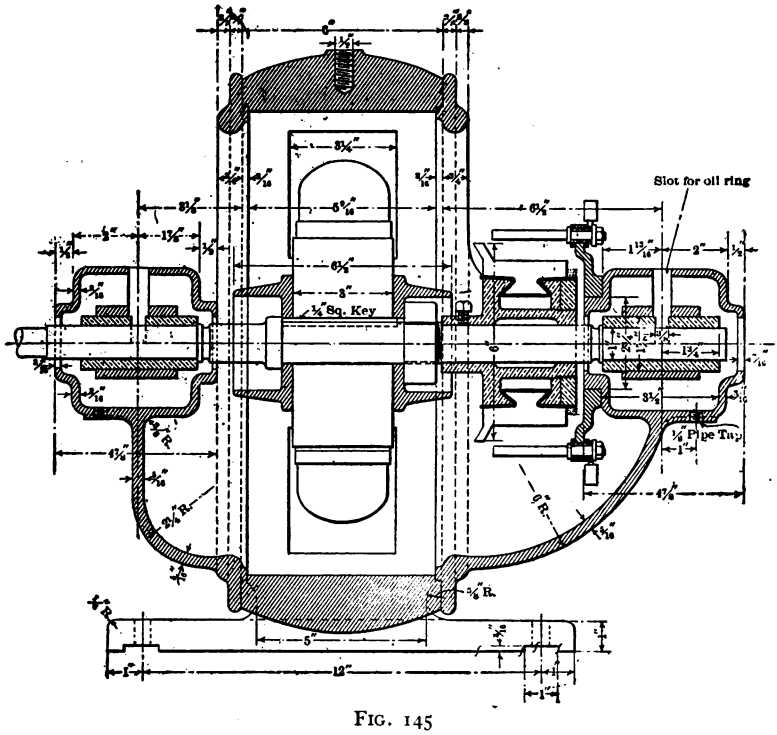


FIG. 145

bored in it into which the barrel of the clamping end-plate may slip. After the discs are compressed to the proper position, the retaining nut may be put in place and set home with a spanner wrench having pins at right angles to the handle instead of pins set into the curved face.

The commutator, the details of which are shown in Figs. 151 to 153, is intended to be 4 ins. in diameter at the barrel and 6 ins. over the lugs, but the diameter of the barrel may be reduced to 3 ins. if preferred. The core (Fig. 152) may be made of cast iron, but is preferably made of hard cast brass; this is also true of the clamping ring shown in Fig. 153. The

segments must, of course, be made of copper, either drop-forged or cast; all of the axial and radial dimensions are shown in Fig. 151. The width of each segment at the face, measured circumferentially, as well as the taper of the segment from the inner edge to the outer, had best be left to the manufacturer from whom the segments are obtained; it is unwise for an amateur to attempt the actual construction of his segments. Segments may be obtained from any of the representative makers by specifying the number of segments, the diameter of the commutator barrel, and the thickness of insulation between the segments, which should be 30 mils.

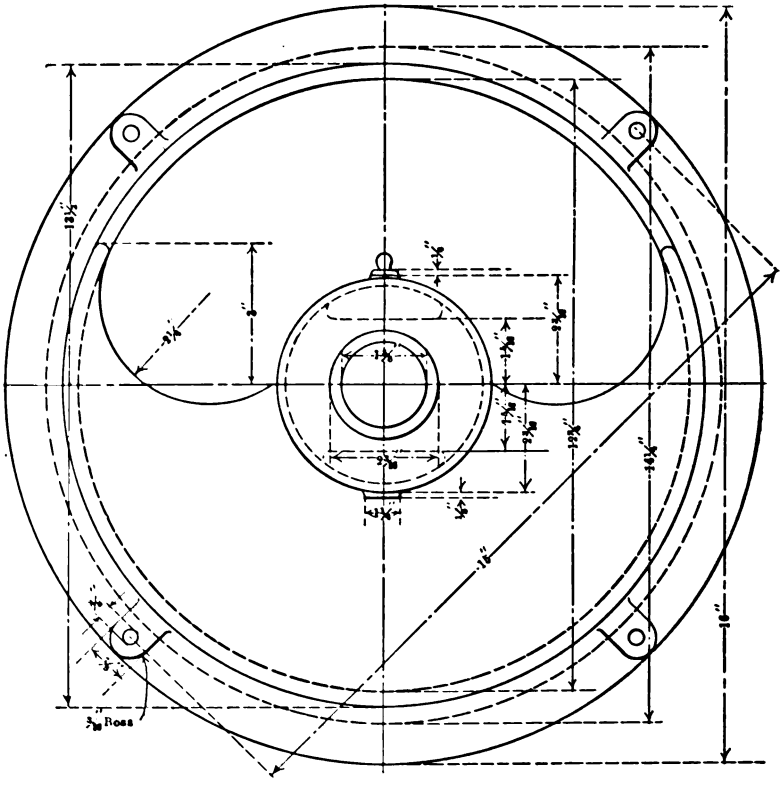


FIG. 146

In putting the commutator together, it will be found advisable to bore a hole 4½ ins. in diameter in a block of wood 1½ ins. thick, and assemble the segments, together with the mica insulating strips, loosely within this hole. Then set the segments up tight by radial pressure from the outside, using a ring of either cast iron or wrought iron about 8½ ins. in diameter at the lug end of the commutator, and a smaller ring of 6 ins. inside diameter

at the other end; these rings each having eight ½-in. screws extending through them radially at equal intervals around the circumference, the screws pressing against eight segments of cast iron, which in turn press the commutator segments together. The point of each screw should be bedded in a shallow hole in the center of the cast-iron segment, against which it presses in order that the segments may not slip out from under the screw.

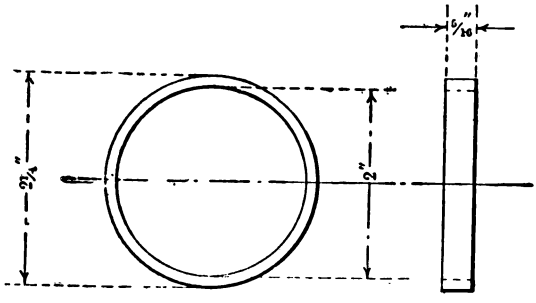


FIG. 147

When the commutator segments have been compressed as tightly as possible, so as to form as nearly as possible a true circle, the complete structure as it stands should be chucked in a lathe and the ends machined to the proper tapers to fit the tapered ring on the commutator core (Fig. 152) and the clamping ring (Fig. 153). The core should then be inserted in the center of the mass of segments without removing the external clamps, and the clamping ring (Fig. 153) put in place and clamped tightly by means of the nut. The external assembling rings and block may then be removed and the commutator mounted on a mandrel and turned true on the outer surface.

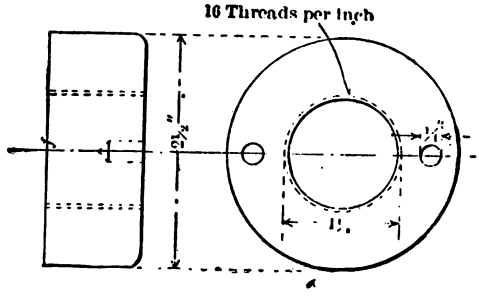


FIG. 148

Fig. 156 shows a convenient form of slide rail which may be used with the machine if belt adjustment is desired. The feet on the yoke ring of the machine have holes drilled

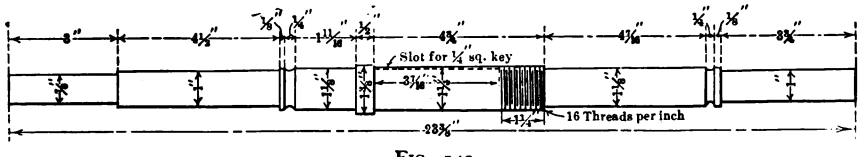


FIG. 149

in them to match the slots in the slide rail, as indicated in Figs. 142 and 145. It is intended simply to bolt the two slide rails down 12 ins. apart

from center to center and mount the machine on them, using screws in the lugs of the slide rails for adjusting the position of the machine.

The armature winding is of the straight-out or barrel type and consists

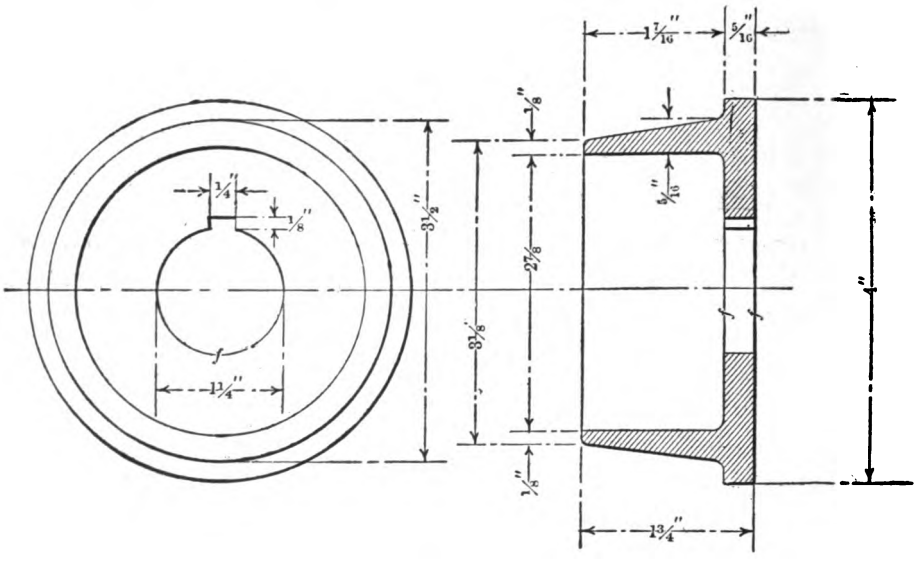


FIG. 150

of 41 coils, each of two No. 8 wires in parallel. The coils may be formed initially by taking two pieces of No. 8 wire 20 ins. long and doubling them together in the center, one wire passing around the bend on the outside of the other, as indicated in Fig. 154. The two wires should be tied temporarily with very fine linen thread to hold them in place during the forming. They may then be bent to the shape shown by Fig. 155, the distance between the two parallel sides of the coil being made such that the coil can be put into two armature core slots between which there are nine teeth. After being bent to the shape shown, each coil should be given a single wrapping of oiled linen tape $\frac{3}{4}$ in. wide and 0.01 in. thick, wrapped so that each convolution laps over one half of the preceding convolution.

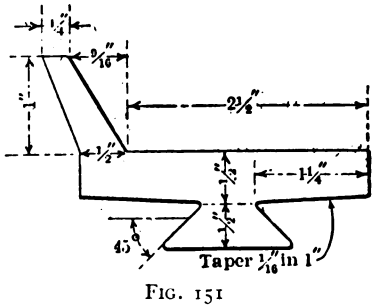


FIG. 151

When all of the coils have been made ready, the slots in the armature core must be insulated by means of troughs of press board 0.015 in. thick,

and the barrel at each end must be given two layers of plain linen tape, heavily varnished after being wound on. The pressboard slot troughs must also be thoroughly varnished on both sides. The core should be put in an oven and baked until the varnish on the troughs and the taping

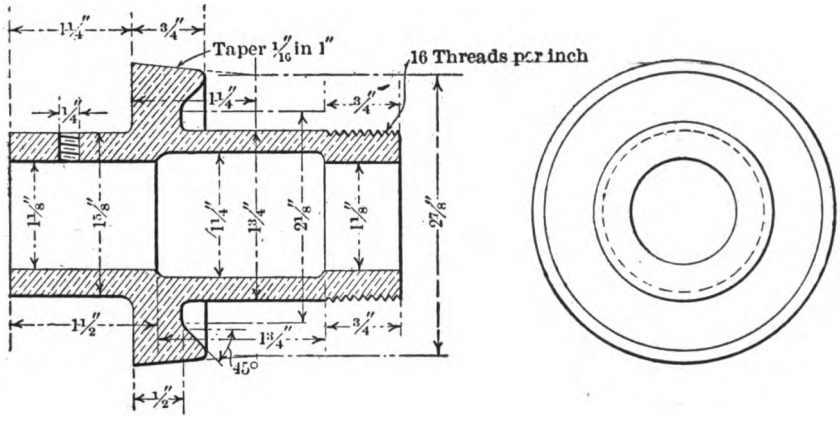


FIG. 152

is thoroughly dried out; only the best grade of orange shellac should be used.

The coils are put on the core in the usual manner, all of the under sides being put in the slots first and the upper halves pulled into place in

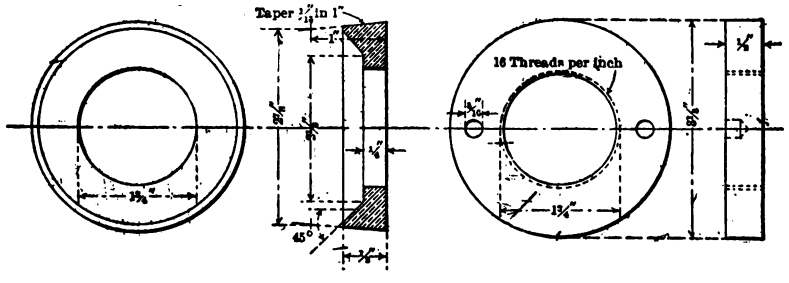


FIG. 153

proper sequence afterwards. The terminals of each coil must be connected to commutator segments between which there are 19 other segments; in the usual armature winder's parlance, each coil will be connected up 1 and 21. The portions of the winding which project beyond the heads of the core must be held down on the cast-iron barrels by means of a single binding of No. 18 brass wire at each end. A binding of No. 20 tinned-iron wire

should be put on the center of the core, with two layers of pressboard between the wire and the core. The bindings on the coil projections at

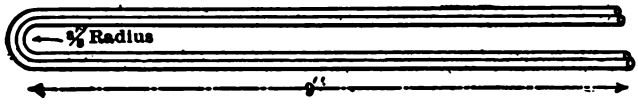


FIG. 154

each end should be insulated from the coils by means of three or four thicknesses of pressboard.

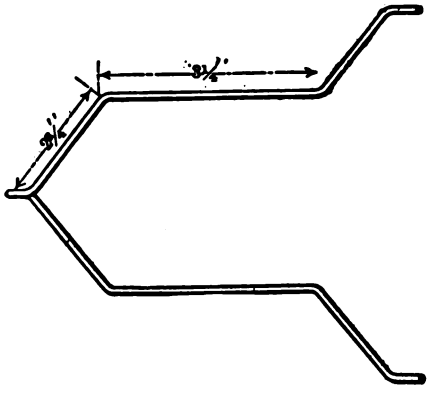


FIG. 155

The field winding consists of four coils of No. 9 single-cotton-covered wire, wound to a depth of 9 layers. Each coil should contain 162 turns of wire, so that the length of the coil parallel with the core will need to be approximately $2\frac{1}{4}$ ins. The four coils are to be connected in series and the entire winding is to be connected in shunt to the brushes, with a suitable rheostat in series, of course. The shunt field current will be about 10 amperes and the rheostat must, of course, be proportioned for this current. The coils should be wound on bobbins of either brass or fiber, the barrel of the bobbin being 3 ins. in diameter

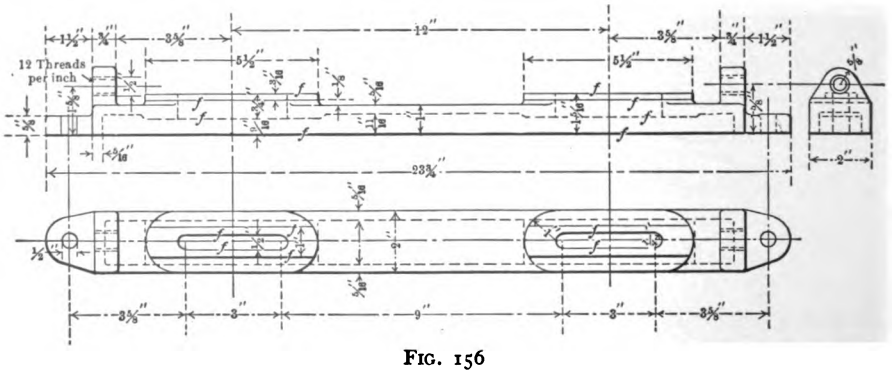


FIG. 156

externally, and the flanges or heads $5\frac{1}{2}$ ins. in diameter. If brass bobbins are used, these must be thoroughly insulated with varnished muslin or canvas before the coils are wound into them. The exterior of each coil

should be covered with a layer of cord, the diameter of the cord being about 3-32 or $\frac{1}{8}$ in.

The brushes must be either of leaf copper or woven wire and each brush face must be $\frac{3}{8}$ x $1\frac{3}{8}$ ins. Four studs and brushes must be used, one brush on each stud. The two brushes diametrically opposite will be of the same polarity, of course, and must, therefore, be connected by means of a rubber-insulated flexible cable, which should be equal in conductivity to No. 0000 wire.

The principal electrical and magnetic data relating to the machine are as follows:

Revolutions per minute	700
E.m.f. at brushes	6 volts
Delivered armature current	100 amperes
Shunt field current	10 amperes
Total armature current	110 amperes
Current density per sq. in. in armature winding	2300 amperes
Current density at brush faces	110 amperes
Current density in field winding	975 amperes

On account of the difference in magnetic quality of different irons, the speed may need to be changed. The proper speed may be ascertained by cutting out the field rheostat and driving the armature at whatever speed is necessary to give 7 volts at the terminals; this should be taken as the running speed of the dynamo.

CHAPTER XVI

SELF-STARTING SINGLE-PHASE INDUCTION MOTOR OF ONE-HALF HORSE-POWER

THE accompanying drawings give all of the essential features of a self-starting induction motor capable of giving one-half brake horse-power on a single-phase circuit of 100 volts and 125 to 133 cycles. The speed of the machine will depend, of course, primarily upon the frequency of the supply current. The synchronous speed at 125 cycles is 3750, and at 133 cycles it is 4000 r.p.m. The actual full-load speed will be something like 3300 r.p.m. at 125 cycles and about 3500 r.p.m. at 133 cycles.

THE STATOR

Fig. 157 is an end view of the stator and Fig. 158 is an axial section of it, showing the arrangement of the brass end plates and the bolts that hold the structure together. The stator core is built up of 108 discs of sheet steel, each 25 mils thick, and allowing for scale and irregularities the mass should be drawn together tightly enough to make the axial thickness 3 ins., as indicated in the engraving. The stator discs are 7 ins. in diameter outside, and the hole in the center is 3 17-32 ins. in diameter; this latter measurement must be absolutely exact. The 24 slots around the edge of the central hole are to be punched by means of the simple punch and die shown by Figs. 159 and 160, these being used in a step-by-step notching press. It is not assumed that the builder will possess one of these presses or buy one for the purpose of building this one motor; but he can easily make the punch and die and have the work done at some shop where such presses are in use.

PUNCH AND DIE

The punch is built up in three pieces, a shank and holder plate of cast iron, a punch pad of ordinary machine steel, and the punch proper, of annealed steel. The punch pad is a simple rectangular plate, in the center of which is worked a socket for the punch, the outline of this socket

being the same as that of the main portion of the opening in the die. The punch is, of course, of the same outline on its face as the complete opening in the die, and the upper part of it is to be made a very snug fit in the hole in the punch pad. The latter is secured to the punch holder by means of four $\frac{1}{4}$-in. flat-head machine screws. In machining the holder, great care must be taken to have the face of it absolutely at right angles with the axis of the shank. The wall of the socket in the punch pad must also be precisely at right angles with the face that matches the face of the holder plate.

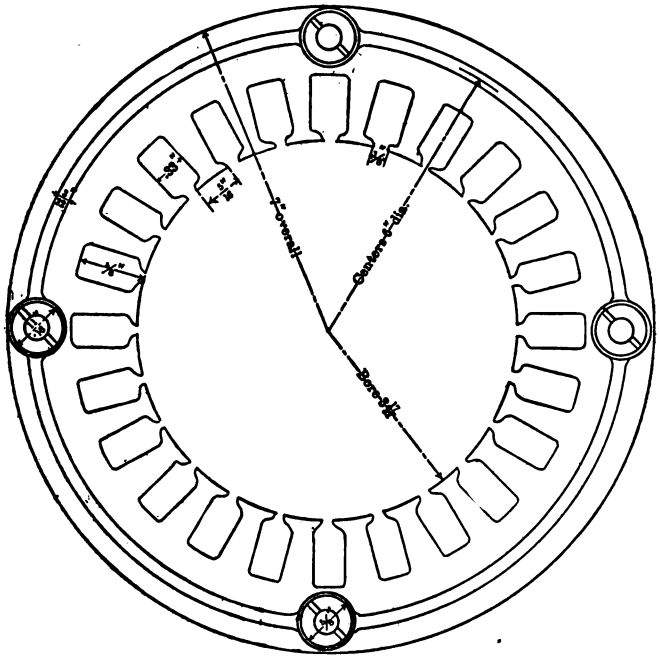


FIG. 157

Fig. 159 shows the punch pad partly unscrewed from the holder, and the punch removed from its socket; it is held in the socket by means of a $\frac{1}{4}$-in. round-nosed set-screw, and a depression should be machined in the side of the punch to allow the nose of the set-screw to seat itself without having to burr the punch. After the punch has been filed to shape, it must be tempered. In first hardening it, the steel should be heated to a bright red and "quenched" in oil or lukewarm water; if very cold water is used the steel will be too brittle. The temper should be drawn in the flame of a Bunsen burner, and the steel should be wiped frequently with an oily rag during the heating. If the reader is not familiar with the

process of "drawing" the temper of tool steel, he had better get this done by an experienced workman.

The die is to be made of annealed steel, of the quality used for this class of work (any dealer will supply the proper quality if told what it is to be used for). The sketches show clearly the shape and dimensions of the die. The dotted line arcs in the upper part of the drawing indicate the inner and outer edges of the stator disc when in position for punching. The hole in the die may be most readily cut by first drilling two holes $\frac{3}{8}$ in. in diameter and one hole $\frac{1}{8}$ in. in diameter along a straight line scribed

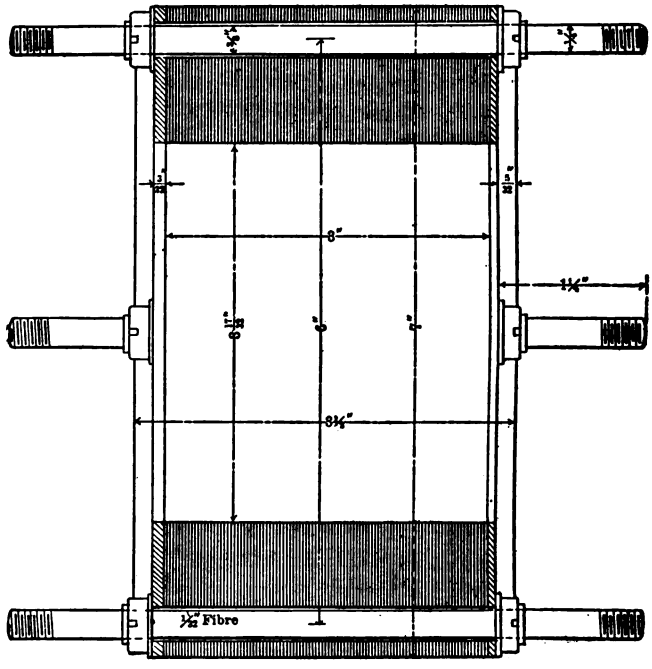


FIG. 158

on the face of the die block; the distances from center to center of these holes are stated in the supplementary sketch between the plan view and the side view of the die. Having drilled these three holes, the superfluous metal must be filed away slowly and very carefully until the desired shape of slot is obtained. Then the hole must be enlarged on the under side of the die block in order to give clearance for the small pieces punched out of the stator discs to free themselves.

The die is bolted to the bolster (which need not be made by the amateur, as the shop in which the punching is done will have bolsters from

which an appropriate selection may be made) by means of two cap screws and two flat-head machine screws. The cap screws also hold the stripper plate, which is a rectangular steel plate $\frac{1}{8}$ in. thick and of the same outline as the base of the die block; it must have a hole cut in it which will come directly over the hole in the die, but the hole in the stripper need not be accurately machined to the shape of the punch; it may be a simple rectangular aperture $\frac{3}{8}$ in. wide and 1 in. long. After the hole in the die has been finished to fit snugly about the punch, which must touch *every part*

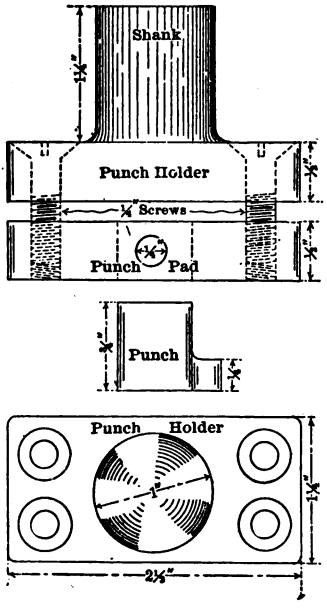


FIG. 159

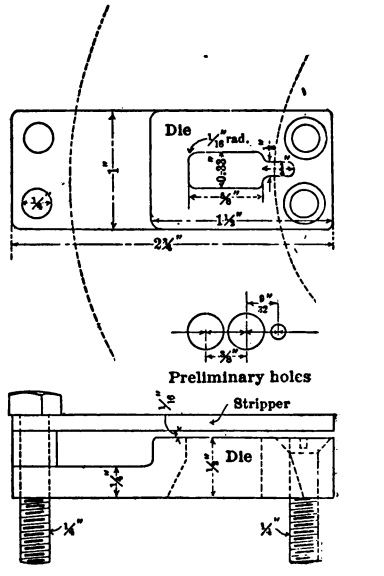


FIG. 160

of the wall of the die hole, the die is to be tempered. The remarks concerning the tempering of the punch apply also to the die.

CLAMPING PLATES AND ASSEMBLY

The brass end plates are cast with the slots in them, the sizes of the slots in these plates being a trifle full, as compared with the punched slots in the core discs. It will not do to use a simple brass ring of an internal diameter large enough to clear the slots in the core; the teeth between these slots must be clamped together tightly along with the body portion in order to reduce as far as possible the humming of the machine when in operation. In assembling the core discs between the brass end plates, the structure must be clamped together by means of two heavy cast-iron

discs 5 ins. in diameter and a 1-in. bolt through the center; this work may be facilitated greatly by the use of ordinary iron clamps such as are found in all machine shops, applying these at points around the outer edge of the stator in order to even up the compression and assist the central clamping bolt. After the discs are drawn to position, the holes near the outer edge may be drilled; if the brass end plates have been made of a hard alloy, the top one will serve as a jig for the drill. In this event it should be drilled before assembling the core discs, but the under plate should be left undrilled; when the discs are assembled, the holes may be drilled clear through them and the under brass plate. A much safer plan, however, is to make a cast-iron jig plate and clamp the discs between it and a plain cast-iron plate for drilling; the brass end plates should be drilled by the same jig plate, but separately.

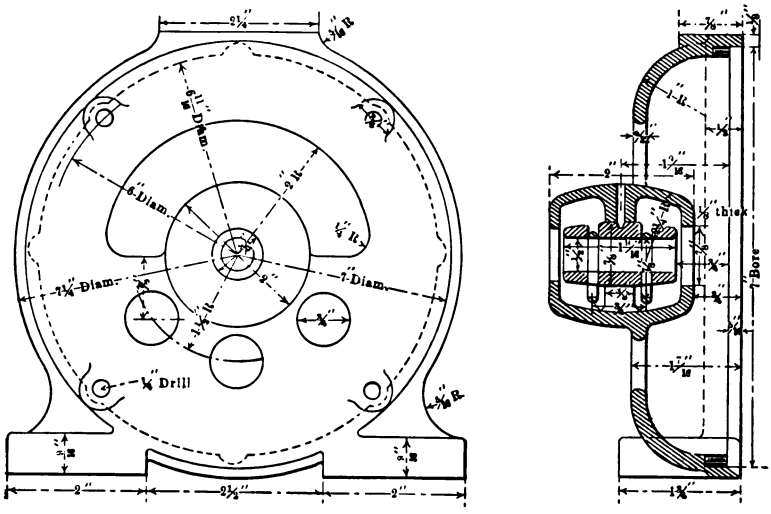


FIG. 161

The four ⅜-in. bolts which hold the stator core together also serve to hold the journal brackets or end caps in place. Fig. 161 shows a face view of one of these end caps and an axial section through the center of it. The drawings require no explanation beyond saying that the caps are to be made of cast iron. (Figs. 157 and 158 show the stator turned 45 degrees from the position that it occupies when clamped between the journal brackets, or end caps, this being done to show the bolts in the sectional view.)

The journal sleeves shown in the engraving are of the self-aligning type, but if the reader is not very skilful at machine tool work it will be pref-

erable to make them perfectly straight, making the outer diameter of the sleeves $\frac{7}{8}$ in. the whole length. No pulley has been shown, as this can be bought for less than it would cost an amateur to make it. The proper size is $2\frac{1}{2}$ or $2\frac{3}{4}$ ins. diameter at the crown and $1\frac{1}{2}$ ins. width of face.

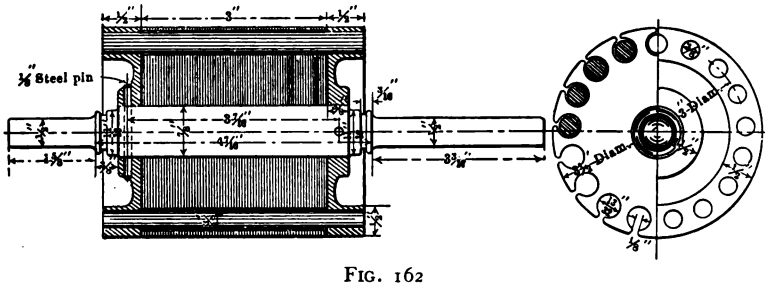


FIG. 162

THE ROTOR

The rotor is shown by Fig. 162. It consists of 108 discs of sheet steel clamped on the shaft between two cast-brass end plates, which also serve to connect the ends of the rotor conductors. There are 17 of these, each $\frac{3}{8}$ in. in diameter and 4 ins. long; the holes in the rotor discs are 13-32 in. in diameter, and may be drilled with the aid of two cast-iron plates between which the discs are temporarily clamped, one of the cast-iron plates to be previously drilled so as to serve as a jig for the drill when the discs are drilled.

WINDINGS

After the stator is finished the slots and end surfaces of the core should be insulated by means of red rope paper 0.015 in. (15 mils) thick, which should be thoroughly varnished with shellac before being put in place. The main stator winding consists of four sections or coils of 56 turns each, of No. 14 double-cotton-covered magnet wire, but this should not be put on until the starting winding is in place. This winding consists of four coils of No. 14 wire, each having 28 turns. Each of these coils should be wound into the proper slots over two blocks of wood (one at each end of the core, as indicated in Fig. 163) which will cause the coils to project $\frac{3}{4}$ in. beyond the face of the stator end plates. After they are wound in place these projecting ends are to be bent upward out of the way of the main coils, which must be wound in the slots between those of

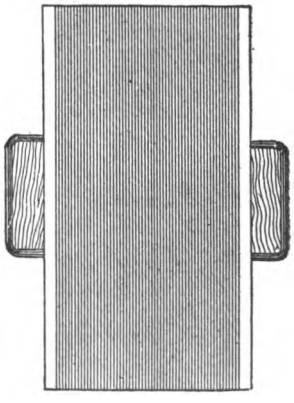


FIG. 163

the starting winding. Fig. 164 indicates this bending upward of the starting coils and also shows the slots into which they are to be wound. They are connected in series with each other, and the connections must be such that if direct current were passed through this winding it would produce alternate north and south poles within the four coils.

After the starting winding is in place and connected up, the main coils should be wound into their slots; two thicknesses of varnished muslin must be laid over the exposed parts of the starting winding just before commencing the winding in of the main coils. These coils are to be wound in their slots as indicated by the elementary diagram, Fig. 164; this shows

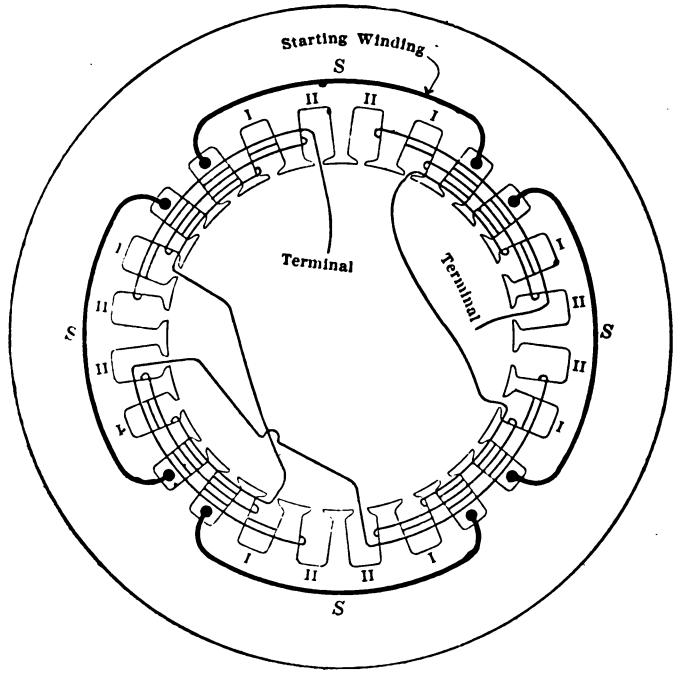


FIG. 164

only one turn in each slot, but the reader will of course understand that 26 turns are to be wound in the inner pair of slots *I*, *I*, before any wire is wound in the outer pair, *II*, *II*. The coils of the main winding, like those of the starting winding, must be connected up in series and in such wise that direct current passing through them would produce four magnetic poles of alternate polarity: north, south, north, south. It makes no difference what the relation is between the direction of the starting coils and that of the main coils; the terminals must be carried out to a three-pole,

double-throw knife-blade switch, as indicated in Fig. 165, and if the connections at first made do not start the motor in the direction in which it is intended or desired to run, it may be reversed by merely reversing the leads from either the main winding or the starting winding, but not both. The switch should be mounted so that the throw is horizontal (unless an additional main switch is provided), in order that it may be left open without danger of accidentally closing by gravity. As the diagram is drawn, throwing the switch to the left puts in both windings, for starting up; when the machine attains something like normal speed, the switch should be thrown quickly to the other side, leaving only the main winding in circuit.

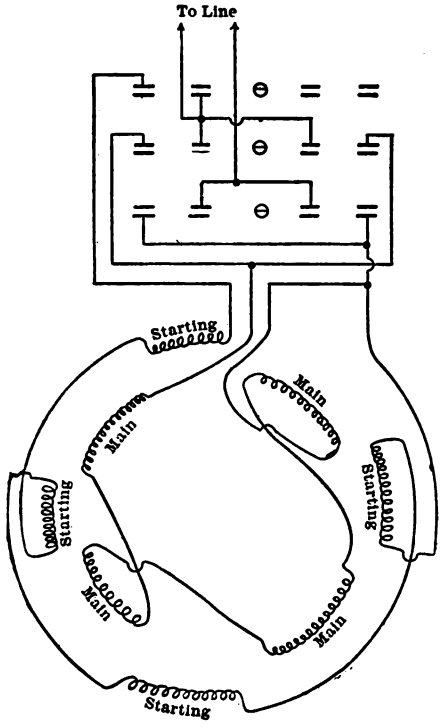


FIG. 165

If the builder prefers to use simpler apparatus, two ordinary double-pole switches may be used, one for the main winding and one for the starting winding, but this arrangement has the slight disadvantage that the user may close one switch and leave it closed for an appreciable length of time before closing the other, which might overheat the winding thus thrown in alone, as the motor would not start up and the winding would be provided with a short-circuited secondary — the rotor conductors. The result would be similar in kind, though less in degree, to that obtained by short-circuiting the secondary terminals of an ordinary transformer with the primary connected to the supply mains. The motor should not be started with any load on it except the countershaft to which it is belted. Even with that it will be found advisable to give the belt a strong pull, to overcome standing friction, when the motor is thrown into circuit.

CHAPTER XVII

ONE-HORSE-POWER SELF-STARTING SINGLE-PHASE INDUCTION MOTOR

THE machine herein described is similar to the one described in the previous chapter. It is a self-starting induction motor capable of giving one brake horse-power on a single-phase circuit of 100 volts and 125 to 133 cycles. The speed of the machine will depend, of course, primarily upon the frequency of the supply current. The synchronous speed at 125 cycles is 3750, and at 133 cycles it is 4000 r.p.m. The actual full-load speed will be something like 3300 r.p.m. at 125 cycles and about 3500 r.p.m. at 133 cycles.

THE STATOR

Fig. 166 is an end view of the stator and Fig. 167 is an axial section of it, showing the arrangement of the brass end plates and the bolts that hold the structure together. The stator core is built up of 225 discs of sheet steel, each 20 mils thick, and allowing for scale and irregularities the mass should be drawn together tightly enough to make the axial thickness 5 ins., as indicated in the engraving. The stator discs are $7\frac{3}{4}$ ins. in diameter outside, and the hole in the center is 4 3-32 ins. in diameter; this latter measurement must be absolutely exact. The 24 slots around the edge of the central hole are to be punched by means of the simple punch and die shown by Fig. 168, these being used in a step-by-step notching press. It is not assumed that the builder will possess one of these presses or buy one for the purpose of building this one motor; but he can easily make the punch and die and have the work done at some shop where such presses are in use.

THE PUNCH

The punch is built up in three pieces, a shank and holder plate of cast iron, a punch pad of ordinary machine steel, and the punch proper, of annealed steel. The punch pad is a simple rectangular plate in the center of which is worked a socket for the punch, the outline of this socket

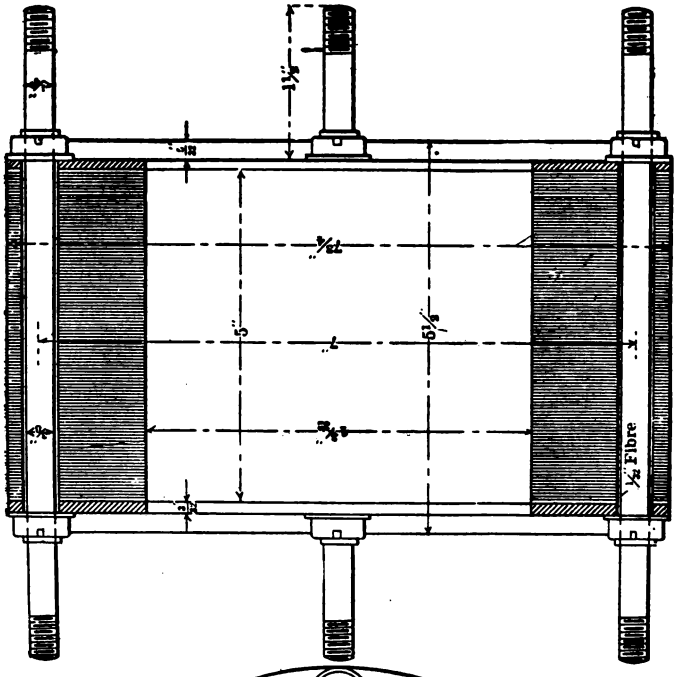


FIG. 167

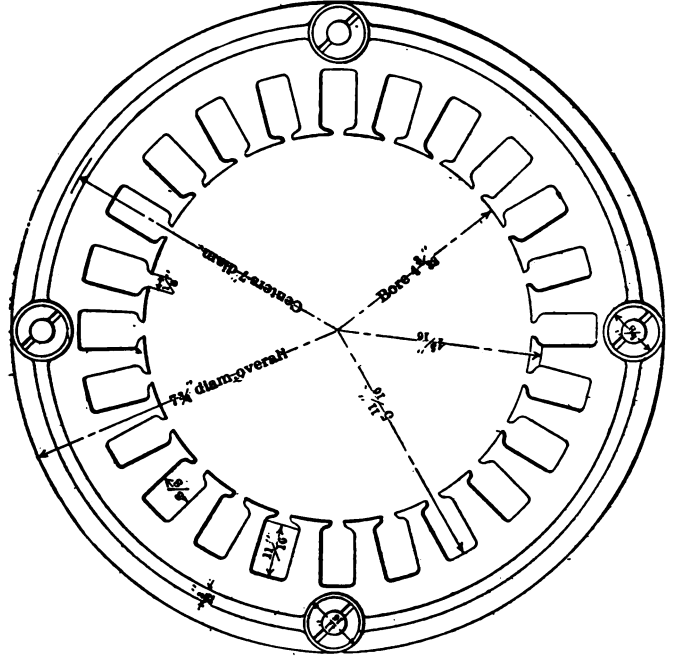


FIG. 166

being the same as that of the main portion of the opening in the die. The punch is, of course, of the same outline on its face as the complete opening in the die, and the upper part of it is to be made a very snug fit in the hole in the punch pad. The latter is secured to the punch holder by means of four ¼-in. flat-head machine screws. In machining the holder, great care must be taken to have the face of it absolutely at right angles with the axis of the shank. The wall of the socket in the punch pad must also be precisely at right angles with the face that matches the face of the holder plate.

Fig. 168 shows the punch pad partly unscrewed from the holder, and

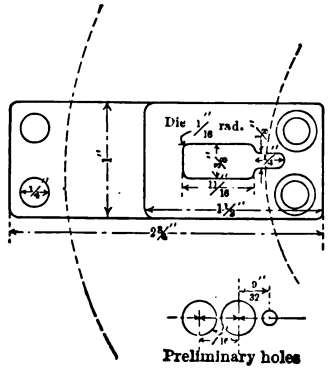


FIG. 168

the punch removed from its socket; it is held in the socket by means of a ¼-in. round-nosed set-screw, and a depression should be machined in the side of the punch to allow the nose of the set-screw to seat itself without having to burr the punch. After the punch has been filed to shape, it must be tempered. In first hardening it, the steel should be heated to a bright red and "quenched" in oil or lukewarm water; if very cold water is used the steel will be too brittle. The temper should be drawn in the flame of a Bunsen burner, and the steel should be wiped frequently with an oily rag during the heating. If the reader is not familiar with the process of "drawing" the temper of tool steel he had better get this done by an experienced workman.

THE DIE

The die is to be made of annealed steel, of the quality used for this class of work (any dealer will supply the proper quality if told what it is

to be used for). The sketches show clearly the shape and dimensions of the die. The dotted-line arcs indicate the inner and outer edges of the stator disc when in position for punching. The hole in the die may be most readily cut by first drilling two holes $\frac{3}{8}$ in. in diameter and one hole $\frac{1}{8}$ in. in diameter along a straight line scribed on the face of the die block; the distances from center to center of these holes are stated in the supplementary sketch between the plan view and the side view of the die. Having drilled these three holes, the superfluous metal must be filed away slowly and very carefully until the desired shape of slot is obtained. Then the hole must be enlarged on the under side of the die block in order to give clearance for the small pieces punched out of the stator discs to free themselves.

The die is bolted to the bolster (which need not be made by the amateur, as the shop in which the punching is done will have bolsters from which an appropriate selection may be made) by means of two cap screws and two flat-head machine screws. The cap screws also hold the stripper plate, which is a rectangular steel plate $\frac{1}{8}$ in. thick and of the same outline as the base of the die block; it must have a hole cut in it which will come directly over the hole in the die, but the hole in the stripper need not be accurately machined to the shape of the punch; it may be a simple rectangular aperture $\frac{3}{8}$ in. wide and 1 in. long. After the hole in the die has been finished to fit snugly about the punch, which must touch *every part* of the wall of the die hole, the die is to be tempered. The remarks concerning the tempering of the punch apply also to the die.

STATOR CLAMPING PLATES AND ASSEMBLY

The brass end plates are cast with the slots in them, the sizes of the slots in these plates being a trifle full, as compared with the punched slots in the core discs. It will not do to use a simple brass ring of an internal diameter large enough to clear the slots in the core; the teeth between these slots must be clamped together tightly along with the body portion in order to reduce as far as possible the humming of the machine when in operation. In assembling the core discs between the brass end plates, the structure must be clamped together by means of two heavy cast-iron discs $5\frac{3}{4}$ ins. in diameter and a 1-in. bolt through the center; this work may be facilitated greatly by the use of ordinary iron clamps such as are found in all machine shops, applying these at points around the outer edge of the stator in order to even up the compression and assist the central clamping bolt. After the discs are drawn to position, the holes near the outer edge may be drilled; if the brass end plates have been made of a hard alloy, the top one will serve as a jig for the drill. In this event it

should be drilled before assembling the core discs, but the under plate should be left undrilled; when the discs are assembled, the holes may be drilled clear through them and the under brass plate. A much safer plan, however, is to make a cast-iron jig plate and clamp the discs between it and a plain cast-iron plate for drilling; the brass end plates should be drilled by the same jig plate, but separately.

JOURNAL BRACKETS

The four $\frac{3}{8}$-in. bolts which hold the stator core together also serve to hold the journal brackets or end caps in place. Fig. 169 shows one of these end caps and an axial section through the center of it. The drawings require no explanation beyond saying that the caps are to be made of cast iron. (Figs. 166 and 167 show the stator turned 45 degrees from the position that it occupies when clamped between the journal brackets, or end caps, this being done to show the bolts in the sectional view.)

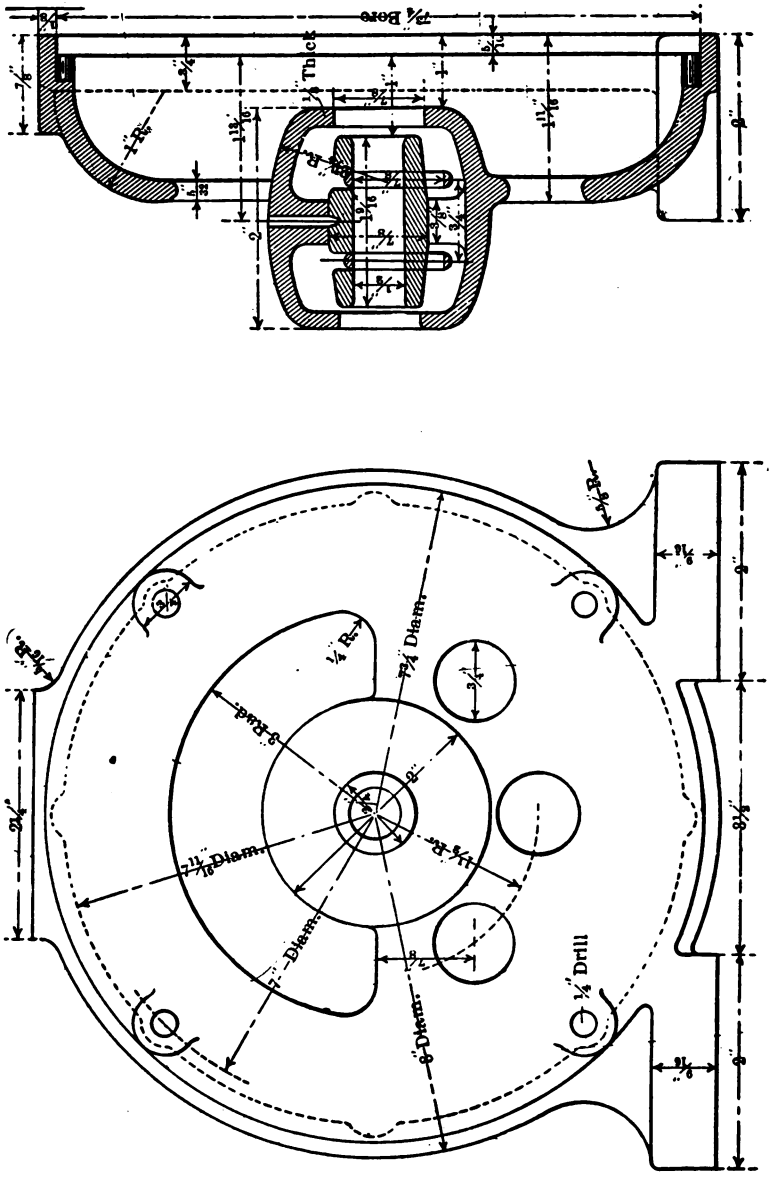
The journal sleeves shown in the engraving are of the self-aligning type, but if the reader is not very skilful at machine tool work it will be preferable to make them perfectly straight, making the outer diameter of the sleeves $\frac{7}{8}$ in. the whole length. No pulley has been shown, as this can be bought for less than it would cost an amateur to make it. The proper size is 3 or $3\frac{1}{2}$ ins. in diameter at the crown and $1\frac{1}{2}$ ins. width of face.

THE ROTOR

The rotor is shown by Fig. 170. It consists of 225 discs of sheet steel 20 mils thick, clamped on the shaft between two cast-brass end plates, which also serve to connect the ends of the rotor conductors. There are 17 of these, each 9-16 in. in diameter and 6 ins. long; the holes in the rotor discs are 19-32 in. in diameter, and may be drilled with the aid of two cast-iron plates between which the discs are temporarily clamped, one of the cast-iron plates to be previously drilled so as to serve as a jig for the drill when the discs are drilled.

STATOR WINDINGS

After the stator is finished the slots and end surfaces of the core should be insulated by means of red rope paper 0.025 in. (25 mils) thick, which should be thoroughly varnished with shellac before being put in place. The main stator winding must not be put on until the starting winding is in place. This winding consists of four coils of No. 11 wire, each having 18 turns. Each of these coils should be wound into the proper slots over


7¾ Bore
Thick
¼ R
¼ R
¼ R

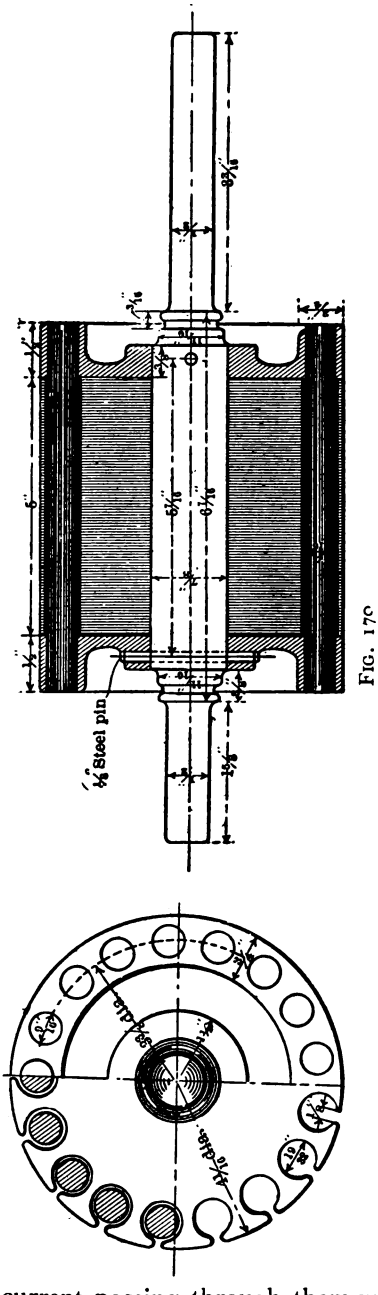


FIG. 170

two blocks of wood (one at each end of the core) which will cause the coils to project 1 in. beyond the face of the stator end plates, as indicated in Fig. 171. After they are wound in place, these projecting ends are to be bent upward out of the way of the main coils, which must be wound in the slots between those of the starting winding. Fig. 172 indicates this bending upward of the starting coils, and also shows the slots into which they are to be wound. They are connected in series with each other, and the connections must be such that if direct current were passed through this winding it would produce alternate north and south poles within the four coils.

After the starting winding is in place and connected up, the main coils should be wound into their slots; two thicknesses of varnished muslin must be laid over the exposed parts of the starting winding just before commencing the winding in of the main coils. These main coils consist each of 36 turns of No. 11 double-cotton-covered wire, and each coil occupies four slots; they are to be wound in their slots as indicated by the elementary diagram, Fig. 172. The diagram shows only one turn in each slot, but the reader will of course understand that 18 turns are to be wound in the inner pair of slots, *I*, *I*, before any wire is wound in the outer pair, *II*, *II*, and that 18 more turns are then wound into these latter slots. The coils of the main winding, like those of the starting winding, must be connected up in series and in such wise that direct current passing through them would produce four magnetic poles of alternate polarity; north, south, north, south. It makes no difference what

the relation is between the direction of the starting coils and that of the main coils; the terminals must be carried out to a three-pole, double-throw knife-blade switch, as indicated in Fig. 173, and if the connections at first made do not start the motor in the direction in which it is intended or desired to run, it may be reversed by merely reversing the leads from either the main winding or the starting winding, but not both.

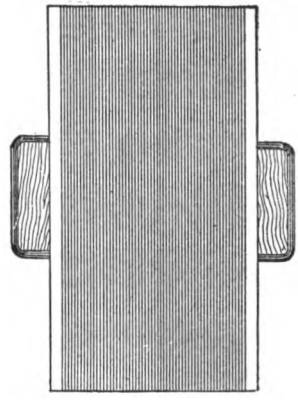


FIG. 171

The switch should be mounted so that the throw is horizontal (unless an additional main switch is provided), in order that it may be left open without danger of accidentally closing by gravity. As the diagram is drawn, throwing the switch to the left puts in bolt windings, for starting up; when the machine attains something like normal speed, the switch should be thrown quickly to the other side, leaving only the main winding in circuit.

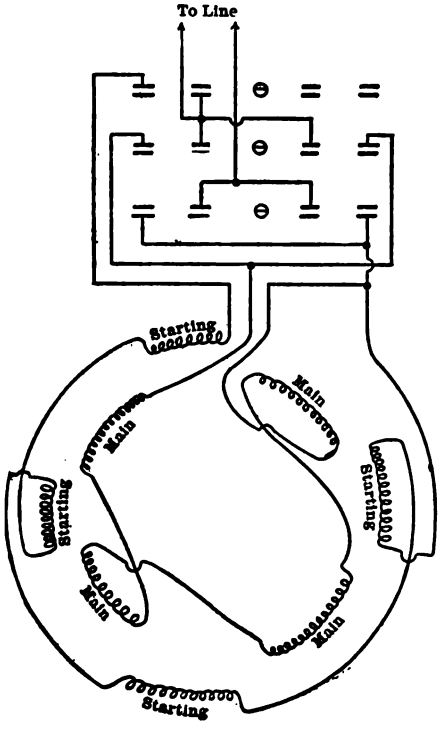


FIG. 172

If the builder prefers to use simpler apparatus, two ordinary double-pole switches may be used, one for the main winding and one for the starting winding, but this arrangement has the slight disadvantage that the user may close one switch and leave it closed for an appreciable length of time before closing the other, which might overheat the winding thus thrown in alone, as the motor would not start up and the winding would be provided with a short-circuited secondary — the rotor conductors. The result would be similar in kind, though less in degree, to that obtained by short-circuiting the secondary terminals of an ordinary transformer with the primary connected to the supply mains. The motor should not be started with

any load on it except the countershaft to which it is belted. Even with that it will be found advisable to give the belt a strong pull, to overcome standing friction, when the motor is thrown into circuit.

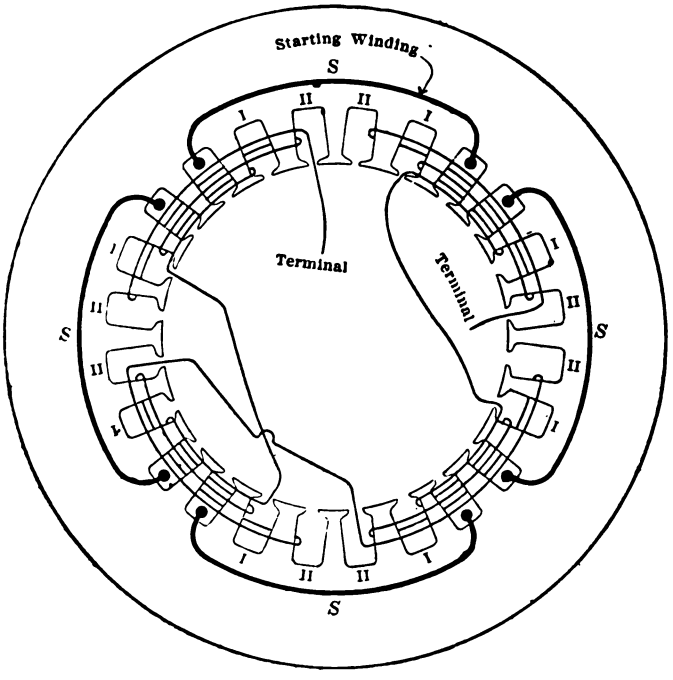


FIG. 173

CHAPTER XVIII

TWO-HORSE-POWER SELF-STARTING SINGLE-PHASE INDUCTION MOTOR

THE self-starting induction motor herein described is capable of giving two brake horse-power on a single-phase circuit of 100 volts and 125 to 133 cycles. The speed of the machine will depend, of course, primarily upon the frequency of the supply current. The synchronous speed at

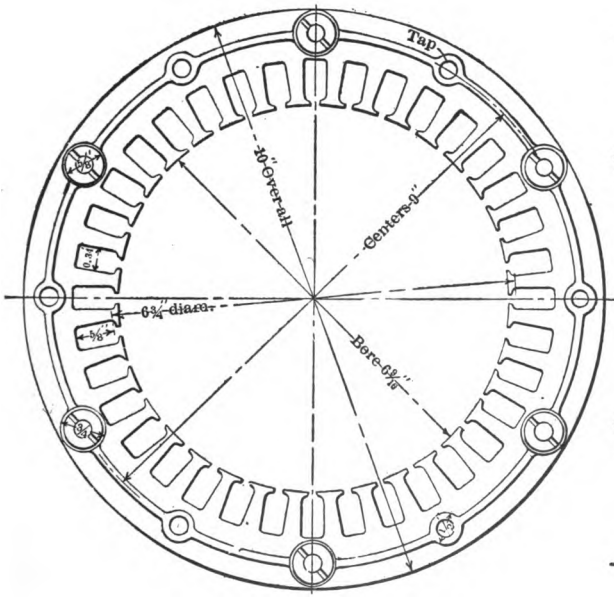


FIG. 174

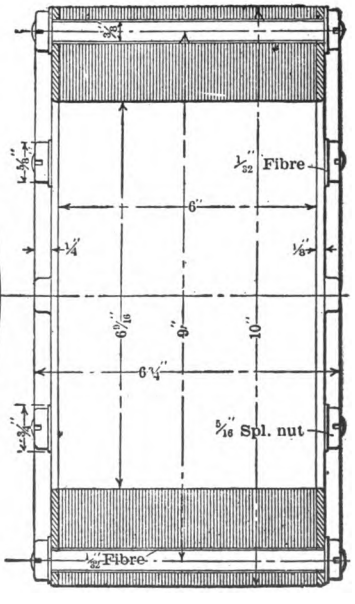


FIG. 175

125 cycles is 2500, and at 133 cycles it is 2666 r.p.m. The actual full-load speed will be something like 2300 r.p.m. at 125 cycles and about 2640 r.p.m. at 133 cycles.

THE STATOR

Fig. 174 is an end view of the stator and Fig. 175 is an axial section

of it, showing the arrangement of the brass end plates and the bolts that hold the structure together. The stator core is built up of 270 discs of sheet steel, each 20 mils thick, and allowing for scale and irregularities the mass should be drawn together tightly enough to make the axial thickness 6 ins. as indicated in the engraving. The stator discs are 9 ins. in diameter outside, and the hole in the center is 6 9-16 ins. in diameter; this latter measurement must be absolutely exact. The 36 slots around the edge of the central hole are to be punched by means of the simple punch and die shown by Fig. 176, these being used in a step-by-step notching press. It is not assumed that the builder will possess one of these presses or buy one for the purpose of building this one motor; but he can easily make the punch and die and have the work done at some shop where such presses are in use.

THE PUNCH

The punch is built up in three pieces, a shank and holder plate of cast iron, a punch pad of ordinary machine steel, and the punch proper, of annealed steel. The punch pad is a simple rectangular plate in the center of which is worked a socket for the punch, the outline of this socket being the same as that of the main portion of the opening in the die. The punch is, of course, of the same outline on its face as the complete opening in the die, and the upper part of it is to be made a very snug fit in the hole in the punch pad. The latter is secured to the punch holder by means of four ¼-in. flat-head machine screws. In machining the holder, great care must be taken to have the face of it absolutely at right angles with the axis of the shank. The wall of the socket in the punch pad must also be precisely at right angles with the face that matches the face of the holder plate.

Fig. 176 shows the punch pad partly unscrewed from the holder, and the punch removed from its socket; it is held in the socket by means of ¼-in. round-nosed set-screw, and a depression should be machined in the side of the punch to allow the nose of the set-screw to seat itself without having to burr the punch. After the punch has been filed to shape, it must be tempered. In first hardening it, the steel should be heated to a bright red and "quenched" in oil or lukewarm water; if very cold water is used the steel will be too brittle. The temper should be drawn in the flame of a Bunsen burner, and the steel should be wiped frequently with an oily rag during the heating. If the reader is not familiar with the process of "drawing" the temper of tool steel, he had better get this done by an experienced workman.

THE DIE

The die is to be made of annealed steel, of the quality used for this class of work (any dealer will supply the proper quality if told what it is to be used for). The sketches show clearly the shape and dimensions of the die. The dotted-line arcs indicate the inner and outer edges of the stator disc when in position for punching. The hole in the die may be most readily cut by first drilling two holes 5-16 in. in diameter and one hole $\frac{1}{8}$ in. in diameter along a straight line scribed on the face of the die block; the distances from center to center of these holes are stated in the supplementary sketch between the plan view and the side view of the die.

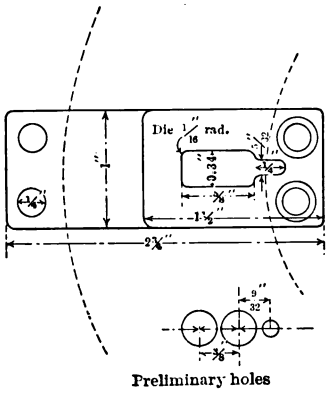


FIG. 176

Having drilled these three holes, the superfluous metal must be filed away slowly and very carefully until the desired shape of slot is obtained. Then the hole must be enlarged on the under side of the die block in order to give clearance for the small pieces punched out of the stator discs to free themselves.

The die is bolted to the bolster (which need not be made by the amateur, as the shop in which the punching is done will have bolsters from which an appropriate selection may be made) by means of two cap screws and two flat-head machine screws. The cap screws also hold the stripper plate, which is a rectangular steel plate $\frac{1}{8}$ in. thick and of the same outline as the base of the die block; it must have a hole cut in it which will come directly over the hole in the die, but the hole in the stripper need not be accurately machined to the shape of the punch; it may be a simple rectangular aperture

$\frac{3}{8}$ in. wide and 1 in. long. After the hole in the die has been finished to fit snugly about the punch, which must touch *every part* of the wall of the die hole, the die is to be tempered. The remarks concerning the tempering of the punch apply also to the die.

STATOR CLAMPING PLATES AND ASSEMBLY

The brass end plates are cast with the slots in them, the sizes of the slots in these plates being a trifle full, as compared with the punched slots in the core discs. It will not do to use a simple brass ring of an internal diameter large enough to clear the slots in the core; the teeth between these slots must be clamped together tightly along with the body portion in order to reduce as far as possible the humming of the machine when in operation. In assembling the core discs between the brass end plates, the structure should be clamped together by means of two heavy cast-iron discs 8 ins. in diameter and a $1\frac{1}{2}$-in. bolt through the center; this work may be facilitated greatly by the use of ordinary iron clamps such as are found in all machine shops, applying these at points around the outer edge of the stator in order to even up the compression and assist the central clamping bolt. After the discs are drawn to position, the holes near the outer edge may be drilled; if the brass end plates have been made of a hard alloy, the top one will serve as a jig for the drill. In this event it should be drilled before assembling the core discs, but the under plate should be left undrilled; when the discs are assembled, the holes may be drilled clear through them and the under brass plate. A much safer plan, however, is to make a cast-iron jig plate and clamp the discs between it and a plain cast-iron plate for drilling; the brass end plates should be drilled by the same jig plate, but separately.

JOURNAL BRACKETS

The four $\frac{3}{8}$-in. bolts which hold the stator core together do not in this case serve to hold the journal brackets or end caps in place. Fig. 177 shows one of these end caps and an axial section through the center of it. The drawings require no explanation beyond saying that the caps are to be made of cast iron.

The journal sleeves shown in the engraving are of the self-aligning type, but if the reader is not very skilful at machine tool work it will be preferable to make them perfectly straight, making the outer diameter of the sleeves $1\frac{3}{8}$ ins. the whole length. No pulley has been shown, as this can be bought for less than it would cost an amateur to make it. The proper size is 4 or $4\frac{1}{2}$ ins. in diameter at the crown and $2\frac{1}{2}$ ins. width of face.

The rotor is shown by Fig. 178. It consists of 270 discs of sheet steel 20 mils thick, clamped on the shaft between two cast-brass end plates,

which also serve to connect the ends of the rotor conductors. There are 29 of these, each $\frac{3}{8}$ in. in diameter and $7\frac{1}{2}$ ins. long; the holes in the rotor discs are 13-32 in. in diameter, and may be drilled with the aid of two cast-iron plates between which the discs are temporarily clamped, one of the cast-iron plates to be previously drilled so as to serve as a jig for the drill when the discs are drilled.

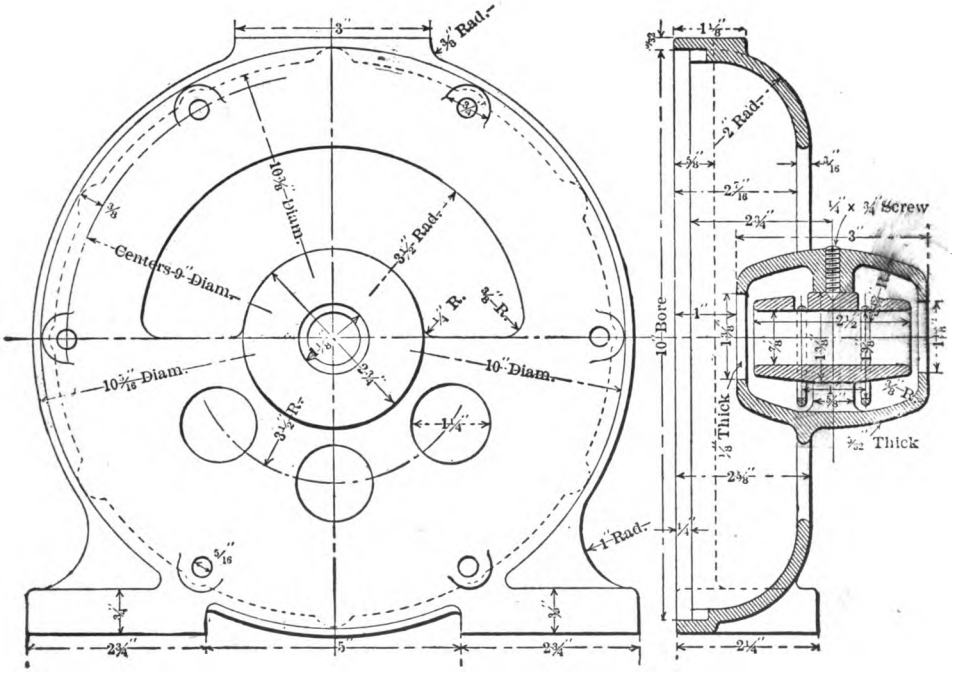


FIG. 177

STATOR WINDINGS

After the stator is finished the slots and end surfaces of the core should be insulated by means of red rope paper 0.025 in. (25 mils) thick, which should be thoroughly varnished with shellac before being put in place. The main stator winding must not be put on until the starting winding is in place. This winding consists of six coils of No. 8 wire, each having 8 turns. Each of these coils should be wound into the proper slots over two blocks of wood (one at each end of the core), which will cause the

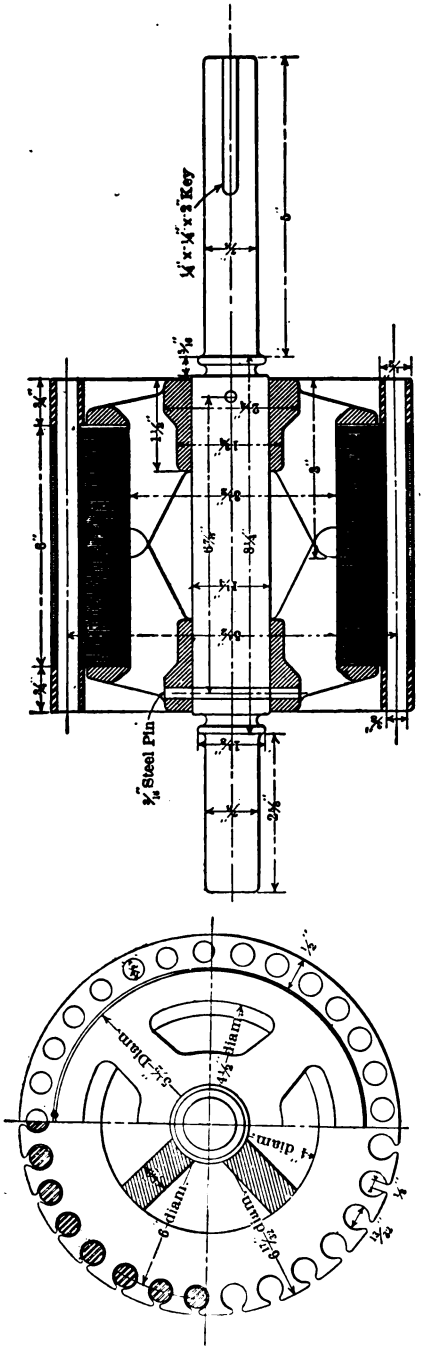


FIG. 178

coils to project 1 in. beyond the face of the stator end plates, as indicated in Fig. 179. After they are wound in place, these projecting ends are to be bent upward out of the way of the main coils, which must be wound in the slots between those of the starting winding. Fig. 180 indicates this bending upward of the starting coils, and also shows the slots into which they are to be wound. They are connected in series with each other, and the connections must be such that if direct current were passed through this winding it would produce alternate north and south poles within the six coils.

After the starting winding is in place and connected up, the six main coils should be wound into their slots; two thicknesses of varnished muslin must be laid over the exposed parts of the starting winding just before commencing the winding in of the main coils. These main coils consist each of 16 turns of No. 8 double-cotton-covered wire, and each coil occupies four slots; they are to be wound in their slots as indicated by the elementary diagram, Fig. 180. The diagram shows only one turn in each slot, but the reader will of course understand that 8 turns are to be wound in the inner pair of slots, *I*, *I*, before any wire is wound in the outer pair, *II*, *II*, and that 8 more turns are then wound into these latter

slots. The coils of the main winding, like those of the starting winding, must be connected up in series and in such wise that direct current passing through them would produce six magnetic poles of alternate polarity: N, S, N, S, N, S. It makes no difference what the relation is between the direction of the starting coils and that of the main coils; the terminals must be carried out to a three-pole, double-throw knife-blade switch, as indicated in Fig. 181, and if the connections at first made do not start the motor in the direction in which it is intended or desired to run, it may be reversed by merely reversing the leads from either the main winding or the starting winding, but not both.

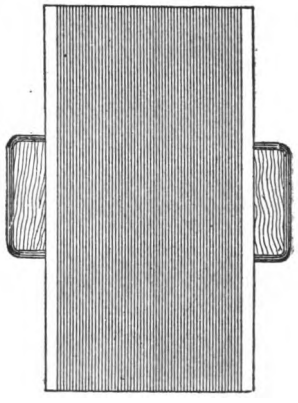


FIG. 179

The switch should be mounted so that the throw is horizontal (unless an additional main switch is provided), in order that it may be left open without danger of accidentally closing by gravity. As the diagram is drawn, throwing the switch to the left puts in both windings, for starting up;

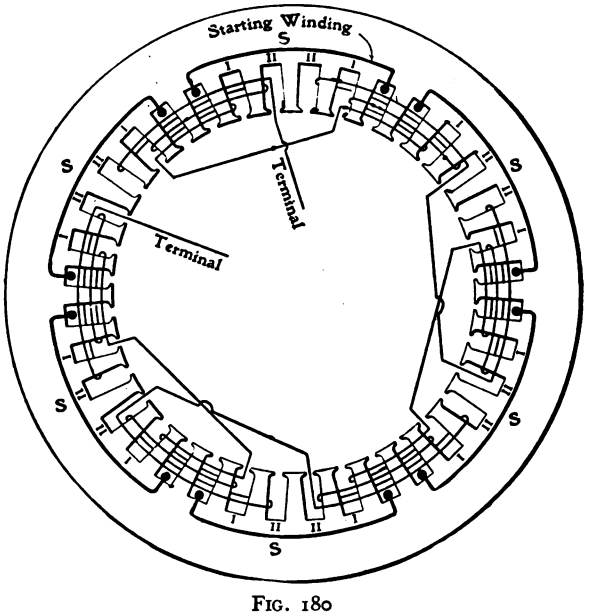


FIG. 180

when the machine attains something like normal speed, the switch should be thrown quickly to the other side, leaving only the main winding in circuit.

If the builder prefers to use simpler apparatus, two ordinary double-pole switches may be used, one for the main winding and one for the starting winding, but this arrangement has the disadvantage that the user may close one switch and leave it closed for an appreciable length of time before closing the other, which might overheat the winding thus thrown in alone, as the motor would not start up and the winding would be provided with

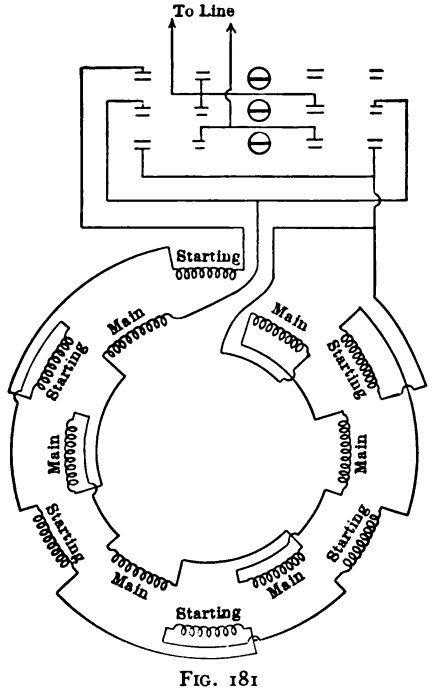


FIG. 181

a short-circuited secondary — the rotor conductors. The result would be similar in kind, though less in degree, to that obtained by short-circuiting the secondary terminals of an ordinary transformer with the primary connected to the supply mains. The motor should not be started with any load on it except the countershaft to which it is belted. Even with that it will be found advisable to give the belt a strong pull, to overcome standing friction, when the motor is thrown into circuit.

CHAPTER XIX

ONE-KILOWATT COMBINED ALTERNATING AND DIRECT-CURRENT MACHINE

THERE are presented in this chapter designs and working drawings for a type of combined alternating and current machine which it is thought will prove generally useful for experimental and laboratory work in alternating and direct currents, and which is applicable on most of the electric-lighting circuits found in practice.

The design contemplates working the machine in a number of different ways:

1. As a direct-current generator or motor.
2. As a single, two, or three-phase generator or motor.
3. As a rotary converter, changing single, two, or three-phase currents to direct current.
4. As an inverted rotary converter, changing direct current to single, two, or three-phase alternating currents.
5. As a phase transformer, changing alternating current of one phase to that of another number of phases.

Some of the foregoing functions may be in operation at the same time; for instance, Nos. 1 and 2 combined would give a "double-current" generator. Also No. 3 or No. 4 may be in operation simultaneously with No. 5.

This machine is designed for 110 volts direct current, and either 80 volts single or two-phase alternating, or 70 volts three-phase alternating. These voltages admit of considerable adjustment, however, by varying the field excitation or speed in case of a generator. The values given represent about the maximum which can be developed continuously.

In operating on single-phase alternating circuits it is necessary to adopt some device which will make the machine self-starting, and this has been provided in the shape of a special switch located in the base of the machine and which, at starting, temporarily changes the connections to those of a series motor which, as is well known, readily starts when alternating current is turned on. The armature is allowed to reach a speed slightly

above synchronism, and the switch is then thrown over to the running position, where the machine operates as an ordinary synchronous motor.

In starting on two or three-phase circuits, the same switch is utilized to break up the field winding into a number of short sections on open circuit, thereby avoiding the high induced e.m.f.'s which would otherwise be produced on turning the alternating current into the armature winding. It will be understood that where two or three-phase currents are employed the machine is self-starting without any special device, by virtue of the rotary field principle. If the starting current, with this arrangement, is found to be objectionably large, it can be avoided by starting on a reduced pressure supplied from small auto-transformers.

The general features of the design are multipolar field having a circular yoke of cast iron with laminated wrought-iron poles cast in. This type is selected because it admits of high magnetic density and short air-gap, and consequently much greater output than does an all cast field, while at the same time it is only slightly more expensive or difficult to construct. An all cast-iron field of the same general design will have only a little more than half the output, and an all cast-steel field, while good magnetically, is scarcely to be considered at present owing to the difficulty in securing reliable steel castings.

Field coils are wound in two or more sections each, and provided with terminals for connection to the starting switch. This is necessary in order to obtain a sufficient reduction in the impedance by connecting the various sections in multiple at the start.

A distributed armature winding is used, with collector rings tapped in at appropriate intervals on the commutator for alternate-current working. The toothed armature core has deep and narrow slots, and is provided with a formed-coil winding, as in direct-current practice.

The minimum number of slots and coils is determined by the number of poles and by the consideration that taps must be made for both two and three-phase working. The quotient obtained by dividing the number of coils or commutator segments by the number of poles must be divisible by two for two-phase working and by three for three-phase working, and hence by two times three for both together. Thus 24 coils and segments are appropriate for a four-pole machine, 36 for a six-pole, and so on.

Six collector rings will be required; ordinarily seven would be necessary, four for two-phase and three for the three-phase. By making one of the two-phase rings the starting point for the three-phase, one ring serves for two, and the total number may be reduced to six.

It would be possible, of course, to use but four rings, obtaining three-phase current by means of two-phase – three-phase transformers, but it is preferable to add two rings and obtain all phases directly from the machine.

The hollow base plate, which is cast in one piece with the bearing pedestals, serves as a housing for the starting switch already referred to. This switch is operated by a lever on the outside, at the front or direct-current end of the machine, and has two positions 120 degrees apart, the starting and running positions respectively. In the starting position the various sections of the field winding are in parallel with each other and in series with the direct-current end of the armature.

In the running position the field sections are in series, giving the maximum resistance, and are placed across the direct-current brushes at the same time alternating current from the single-phase mains is turned into the collector rings.

A pulley having a heavy rim for the purpose of securing a considerable fly-wheel effect will be found advantageous in adding to the smooth running of the machine, particularly when used as a rotary from the alternating-current end.

A pulley of this kind will also be useful where the machine is to be used as a generator direct belted to a gas or gasoline engine. The need for a considerable amount of momentum in the running parts of a rotary is real and genuine, for without it there is a disagreeable oscillation or "pumping," which makes synchronism unstable and sometimes causes the machine to break out of step even before full load is reached.

The bearings are of the ring-oiling type, and of a form which gives good lubrication without the disadvantage of having oil thrown off outside the bearing.

The running qualities of these machines will doubtless prove quite satisfactory. There is not likely to be trouble from sparking, in spite of the fact that the armature is multiple wound, in which, ordinarily, a slight lack of symmetry in field strength would cause heating and sparking. The connections already made to the collector rings for another purpose serve also as equalizers, which permit equalizing currents to flow and thus counteract any slight inequality in the various field poles.

Armature reaction may be guarded against by clipping off the corners of every third lamination of the field poles. This will have the effect of increasing the density in the pole tips to practical saturation, thus avoiding further distortion by armature currents and giving practically a fixed point of commutation for all loads.

Heating in the armature and field windings should not prove serious, for the current densities employed are moderate, considering the size of machine. In the pole-pieces, heating would ordinarily be expected, due to the short air-gap and hign density, but their laminated construction will entirely obviate this difficulty.

While primarily intended for use on 125-cycle circuits, modifications

will be indicated enabling these machines to be used on 60-cycle circuits also. This involves either a reduction in speed of one half, with a correspondingly reduced output and voltage, or a reduction in the number of poles to one half, keeping the speed and output the same, but necessitating a somewhat more difficult change in connections and winding.

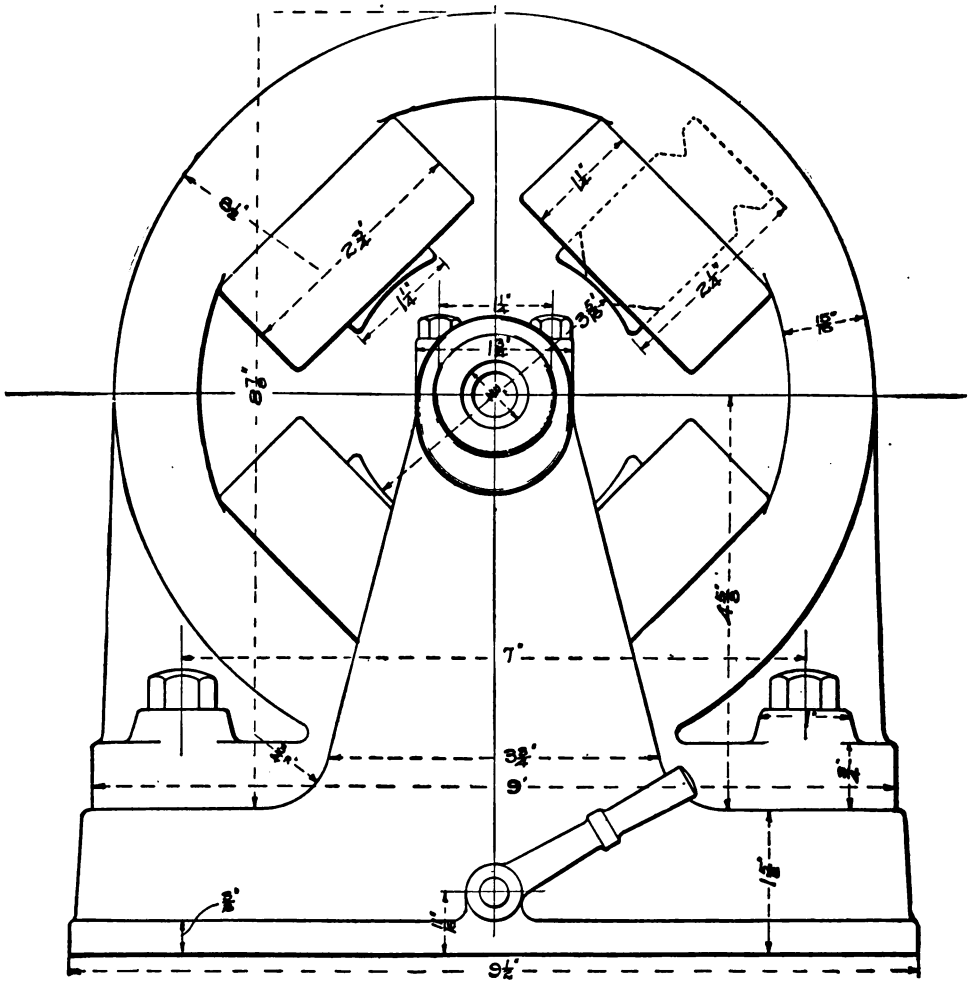


FIG. 182

Referring now to the one-kilowatt machine, Fig. 182 shows an end view of the field magnet and base. There are four poles cast into the yoke, which forms a separate casting and is bolted to the base plate by four 7-16-in. by 1½-in. hexagon cap screws. The poles are built up of

plain rectangular strips of soft iron about No. 22 gage, which are clamped between two heavier plates by one or more long flat-head bolts.

The pattern for the field casting should be made just as though it were for an all cast field, the laminated pole-pieces being laid in the mold after the pattern has been drawn, and the iron poured in around them. The natural shrinkage of the metal on cooling will cause the poles to be tight and secure. It would give additional security, however, to notch the poles before casting in as indicated by the dotted lines. Still another plan is to leave the end plates short, and to spread the laminations apart where they enter the yoke. This will allow the iron to fill in the interstices and so obtain a good hold on the pole. As the poles have been left with square ends, they must now be bored out 3 5-16 ins., and the corners slightly rounded.

Fig. 183 is a longitudinal half section of the assembled machine, which shows the construction of the armature, bearings, commutator, and collector rings, and also the location of the starting switch in the base.

The armature core is built up of soft steel discs about No. 27 gage; two heavier discs of wrought iron, 3-16 in. thick, are provided at the ends as a reinforcement for the teeth, and the whole is clamped between two cast-iron flanges run up on threads cut in the shaft. These flanged pieces serve also as a support for the "straight-out" winding.

Plain round discs may be used in building the core and the slots milled out, being careful, however, to take the discs apart after milling and insulate them with paper or japanning. The keyway in the disc insures their registering when reassembled, in spite of possible slight inaccuracy in milling the slots. It is not necessary to insulate the discs from the shaft if they are fairly well insulated at all other points.

The bearings have a central rib $\frac{3}{8}$ in. thick, which supports the brass or bronze sleeve forming the journal proper. The oil pockets at either side of the web communicate by means of a slot cored out in the web, so that the oil level may remain the same on each side. The oil rings are $\frac{1}{8}$ in. wide and ride on the shaft through grooves turned eccentrically in the sleeve.

The commutator has a steel sleeve fitting the shaft, upon which are two flanges, one solid with the sleeve and the other threaded on it and tightened by means of a spanner wrench applied to holes drilled in its face. Both flanges are undercut at an angle of about 60 degrees, to hold the segments in place.

Probably the best way to construct the commutator is to turn up a copper casting of the required section, and then slit the cylinder into 24 segments by means of a 1-32-in. cutter, in a milling machine. The segments are then built up with 1-32-in. mica between, and insulated from the sleeve by 1-16 in. of mica or other good insulation.

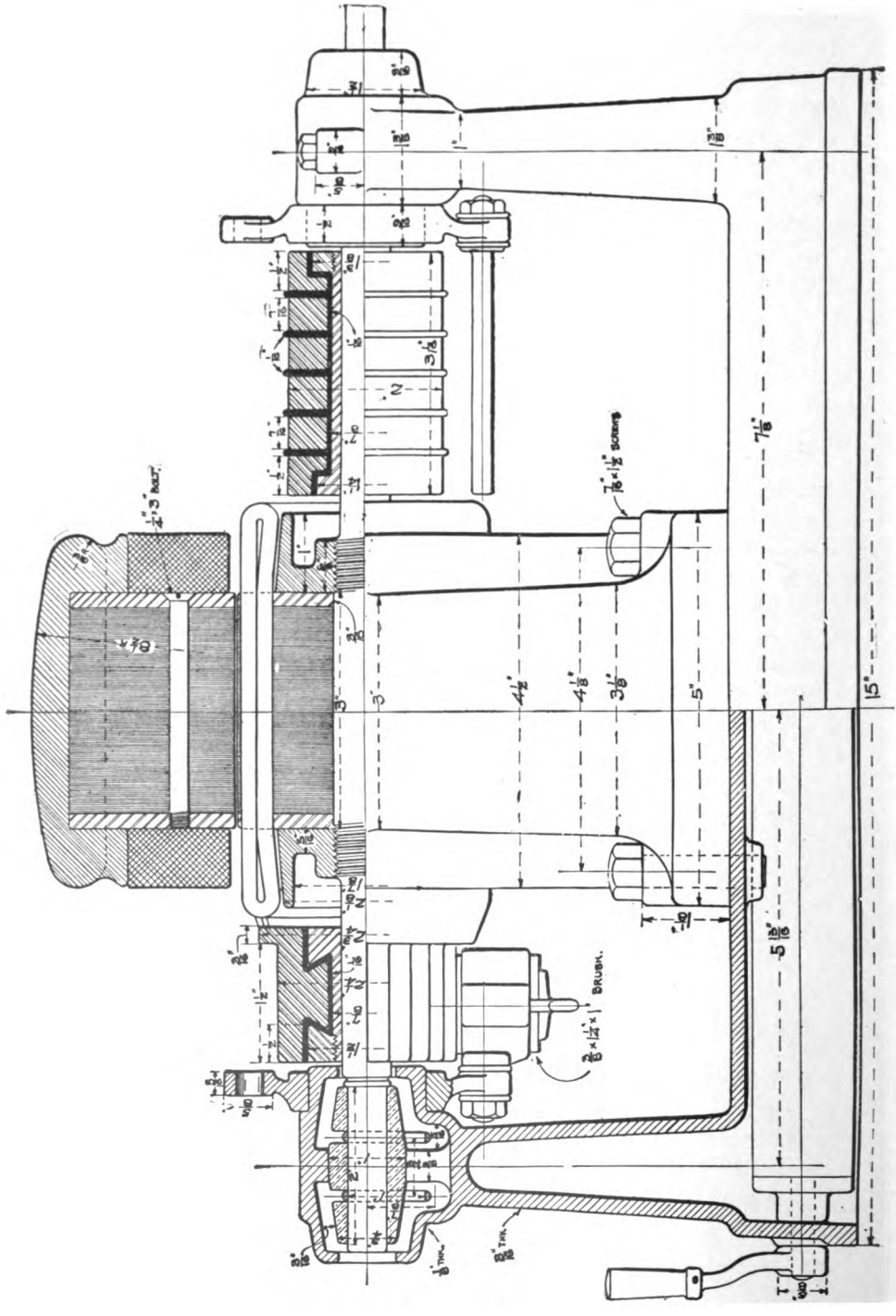


FIG. 183

The collector rings are similar in construction. The two end rings are counter-bored to let in the flanges of the sleeve, which, in this case, need not be undercut. The other rings are plain round and are simply slipped over the insulating sleeve, and separated from each other by 1-16-in. fiber, or equivalent insulation, which is allowed to project somewhat above the surface of the rings.

Connections to the rings are made by drilling in from the back side and soldering in short wires, No. 12 or No. 14, which should be carefully insulated where they pass through other rings by small fiber or rubber tubes. These wire leads are made only just long enough to project a short distance from the back ring, and are there soldered to some thin copper strips taped and laid in the bottom of the armature slots, six of which have been cut 1-16 in. deeper than the rest to accommodate these connections. It will be the more convenient to make all these connections permanently and test them before laying on the armature coils.

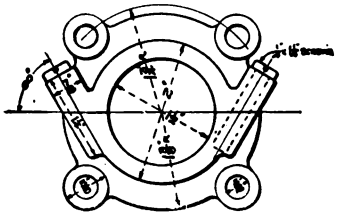


FIG. 184

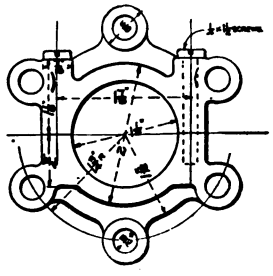


FIG. 185

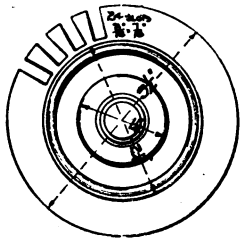


FIG. 186

Fig. 184 shows the brush ring for the alternating-current end, and Fig. 185 the one for the direct-current end of the machine. They are made in halves, held together by screws, which will facilitate in assembling the machine. The direct-current ring has four lugs for supporting the brush-holder, and the alternating-current ring has six, one for each of the six collector rings.

Fig. 186 shows an end view of the armature core and Fig. 187 a development of the armature winding. The core has 24 slots 3-16 in. wide and 7-16 in. deep. Every fourth slot is made $\frac{1}{2}$ in. deep to allow space for connections to the rings. The teeth are plain straight and the armature must be banded after the coils are in place.

The armature winding is of the type known as "straight out" and is composed of form-wound coils of No. 20 double-cotton-covered wire, each coil consisting of 16 turns arranged 4 wide and 4 deep. The coil is wound as a simple straight loop, and after receiving a wrapping of tape it is bent until it will span one quarter of the armature circumference. One

side of a coil occupies the top of a slot, and the other side of the same coil occupies the bottom half of a slot 90 degrees, or six slots, in advance of the first. Thus arranged, the coils interleave in a very compact mannner and the space required for cross connection is reduced to a minimum.

The terminals are brought out at the apex of the coil and are connected directly to the commutator segments, the beginning of one coil and the ending of the adjacent coil connecting to the same segment. The advantage in bringing the terminals straight out to the commutator in this way is that, in addition to being more convenient, it permits the brushes to be placed opposite the poles, where they are more accessible than when placed between the poles.

Fig. 188 shows details of the brush-holders. The direct-current holders are of simple construction, but neat in appearance, and are intended for radial graphite or carbon brushes $\frac{3}{8}$ in. thick, $1\frac{1}{4}$ ins. wide, and 1 in. long.

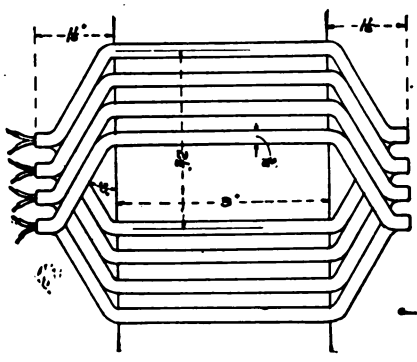


FIG. 187

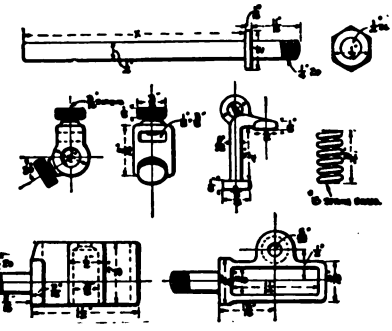


FIG. 188

The necessary tension on the brush is supplied by an open-coil spring concealed in a hollow lug cast on the side of the holder, and acting on a small pressure foot shown separately in the drawings. By lifting the pressure foot by means of the eye at its top and turning it half around, a brush may be readily removed from or inserted into the holder.

The alternating-current brush-holders are carried upon studs supported from the brush ring, and have slots $\frac{1}{8}$ in. by $\frac{3}{8}$ in. for copper-leaf brushes. There need not be any spring tension provided, as the natural spring of the brush will be sufficient to insure good contact. Two thumb screws are provided, one to hold the brush and the other to clamp the holder upon its stud in the desired position. The studs are of different lengths, the dimension marked *X* having the values $3\frac{1}{8}$ ins., $2\frac{5}{8}$ ins., $2\frac{1}{8}$ ins., $1\frac{5}{8}$ ins., $1\frac{1}{8}$ ins., and $\frac{5}{8}$ in. for the six studs. Quarter-inch brass rod may be used to make these from, the collars being soldered or threaded on and the ends

threaded for a hexagon nut. All brush-holders and parts should be made in brass or bronze.

Figs. 189 and 190 are diagrams to be followed in making taps to the collector rings. The four-pole arrangement, Fig. 189, is intended for operating on 125-cycle circuits, and the two-pole, Fig. 190, for 60 cycles. These connections should be made at the back of the commutator before it is placed in position on the shaft. In the four-pole arrangement, for instance, segments No. 1 and No. 13 are connected together and to a lead marked No. 1, which goes to collector ring No. 1, and similarly for the others. Thus connected, single-phase current may be obtained from rings 1–2 or 3–4. Two-phase current from 1–2 and 3–4 and three-phase current from 1–5–6. The output and voltage with these various connections are as follows: Direct current, 10 amperes at 110 volts; single-phase alternating,

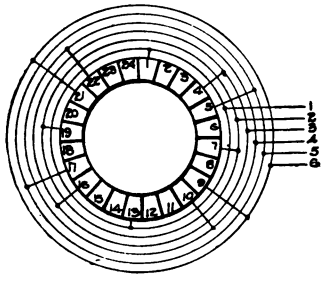


FIG. 189

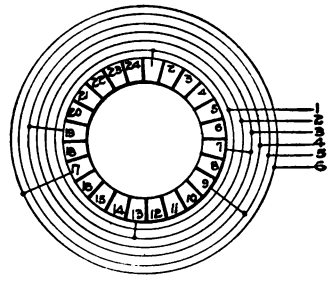


FIG. 190

10 amperes at 80 volts; two-phase alternating, 7 amperes per phase at 80 volts; three-phase alternating, 6 amperes per phase at 70 volts.

Fig. 191 shows a form of fly-wheel pulley which is recommended as conducing to smooth running, for reasons already referred to. This pulley is of cast iron and should be turned perfectly true all over and carefully balanced, as should also the armature. These rotating parts will be required to run at 3750 r.p.m. on 125 cycles, and unless precautions are taken the vibration will be excessive.

Fig. 192 is a detail of the armature shaft. This is designed to be turned from a piece of $\frac{3}{4}$-in. cold-rolled steel, and for this reason the customary collar at one end has been omitted, and instead threads are cut on both ends for receiving the end plates of the core. This does away with expensive forgings and provides a shaft requiring only a minimum amount of turning. Small grooves are provided at the journals which prevent oil from creeping along the shaft and being thrown off outside the bearing. There are two keys on the shaft, one for the core punchings and the other to hold on the pulley.

Fig. 193 shows the arrangement of the switch cylinder and conta

for the single-phase starting device. There are 30 contact fingers, each $\frac{5}{16}$ in. wide, fastened to a strip of fiber $\frac{1}{4}$ in. thick, which in turn is screwed to the under side of the cast-iron base of the machine. Upon a cylinder of hard wood or fiber $1\frac{1}{4}$ ins. in diameter are arranged two rows of brass pieces, sunk in grooves cut on the cylinder and upon which the stationary contact fingers press.

The cylinder may be rotated through an angle of 120 degrees by means of a handle on the outside. The contacts on the cylinder are 120 degrees apart, which allows sufficient space for the first set to leave contact before the second comes into contact, this being essential to avoid short circuit.

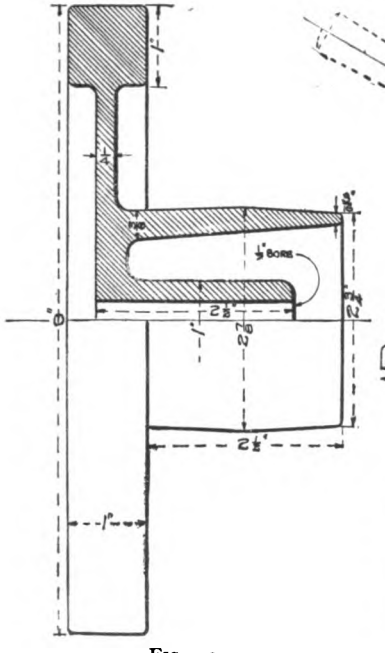


FIG. 191

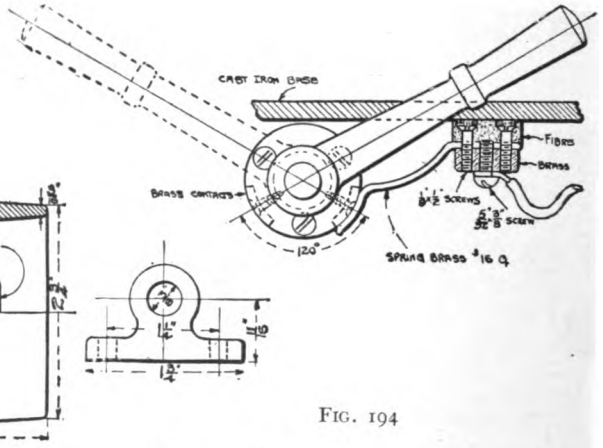


FIG. 194

Fig. 195 shows a diagram of connections for the starting switch, by means of which its action may be readily traced out. Numbers 1–12 represent the sectional field winding, there being four coils, each of which is wound in three sections of approximately equal resistance. There are then twelve pairs of ends which lead down into the base of the machine and are connected to the stationary contact pieces, which are represented by the upper row of small circles. The remaining three pairs of contacts connect to the direct-current brush leads, the single-phase rings, and the single-phase mains, respectively.

The lower rows of circles represent the contact pieces mounted on the cylinder, and these are connected, as here indicated, by means of wires laid in grooves upon the cylinder and occupying that portion of the cylinder over which the contact fingers do not pass.

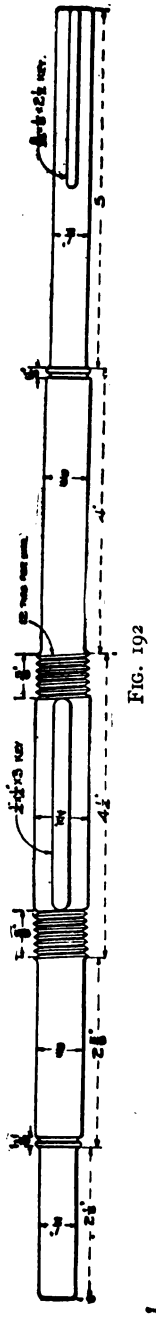


FIG. 192

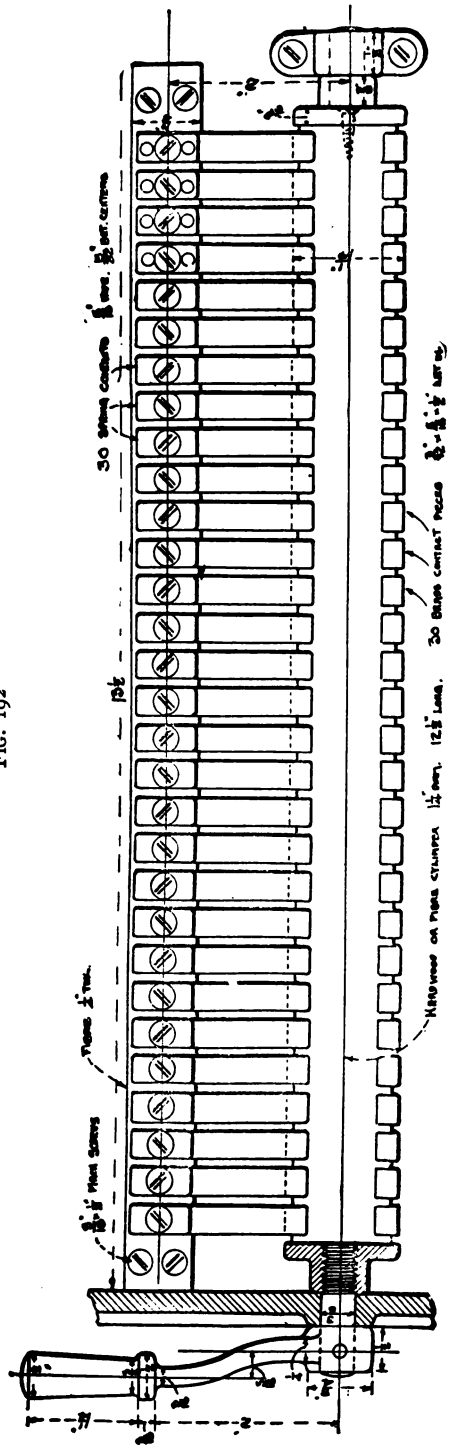


FIG. 193

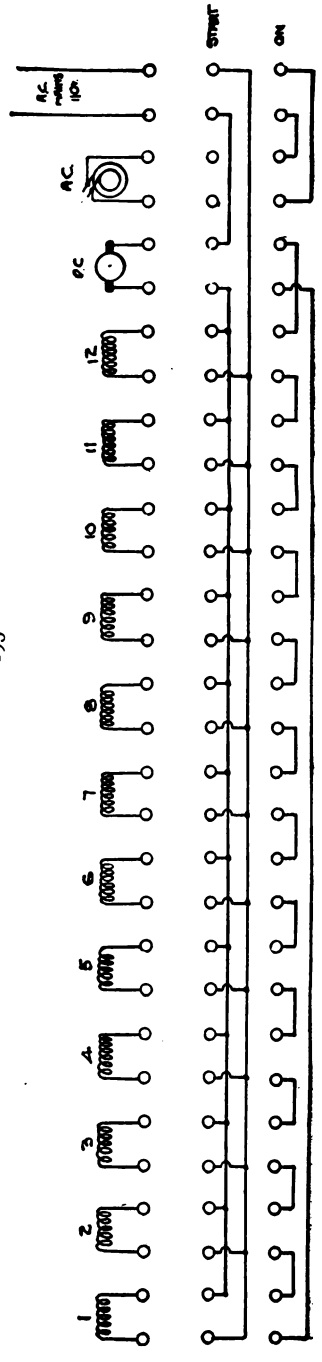


FIG. 195

To operate the machine at 110 volts direct current or 125-cycle alternating, no changes are necessary. For 60-cycle alternating, however, the number of poles is reduced one half by reversing the terminals of any two successive field coils, and the armature winding must be changed to a bipolar one.

Another plan is to reduce the speed one half, thus halving the voltage and output and connecting the field coils in series-multiple so that they will still take the same current as at the higher voltage. In operating the machine as a converter, if it is desired that the direct-current output be at 110 volts, the single or two-phase input must be at 80 volts. This relation of voltage is fixed and can be expressed by direct-current volts $\times$ .707 = alternating volts, and for three-phase by direct-current volts $\times$ .612 = alternating-current volts. So that if the alternating circuit is of 52 or 104 volts the machine should be supplied at the proper voltage through a transformer. An old 15-light transformer will serve for this purpose, and it should be arranged so that its secondary voltage can be varied to some extent by changing the number of secondary turns in circuit, thus giving a means of adjusting the direct-current voltage.

The following is a brief summary of the data for winding and general dimensions, and shows the method of calculating same:

Four-pole machine, 3750 r.p.m.; armature, $3\frac{1}{4}$ ins. diameter, 3 ins. long; 24 slots, 3-16 in. wide, 7-16 in. deep; total number of conductors, 768; 24 coils, No. 20 wire, 4 wide, 4 deep; No. 20 has 1021 circ. mils, diameter d.c.c., .042 in.; direct-current output at 400 c.m. per ampere, 10 amperes; useful lines per pole $\frac{115 \times 10^8}{768 \times 62.5} = 240{,}000$; total lines, 330,000.

Part	Material	Total lines	Cross sect.	B.	H.	L.	Amp. turns
Armature	Wrought iron	120,000	2.25 sq. ins.	53,300	14	1.4 in.	20
2 air-gaps	Air	240,000	4.5 "	53,300	16,800	.06 "	1,000
4 teeth	Wrought iron	240,000	2. "	120,000	180	.45 "	80
2 cores	Wrought iron	330,000	3.75 "	88,000	20	1.5 "	30
1 yoke	Cast iron	165,000	4. "	41,300	74	4.25 "	315
Total							1445

The table above gives a total of 1445 ampere-turns or 725 ampere-turns per coil; mean length, 1 turn, 11 ins.

Circ. mils in shunt wire $\frac{11 \times 11 \times 725}{25 \times 12} = 290.$

Use No. 25 wire, 320 c.m., .028 in. d.c.c. 1155 turns (approximate) per coil; 25 layers, 45 turns wide.

Wind in three sections. Bring out terminals from each section.

Resistance of shunt field $= \frac{4 \times 1155 \times 11 \times .97}{1000 \times 12} = 136$ ohms.

Normal shunt current, .63 ampere. Use a rheostat of about 50 ohms total resistance in shunt-field circuit.

Weight of wire in shunt coils $= \frac{4 \times 1115 \times 11 \times .97}{1000 \times 12} = 4.1$ pounds.

Length of wire, each armature coil $= \frac{16 \times 13}{12} = 17.4$ feet.

Total length of wire, armature, $= 24 \times 17.4 = 417$ feet.

Total weight of armature wire $= \frac{417 \times 3.09}{1000} = 1.3$ pounds.

Resistance of armature $= \frac{417 \times 10.1}{1000 \times 16} = .26$ ohm.

Drop in armature at full load $= 10.63 \times .26 = 2.76$ volts.

CHAPTER XX

TWO-KILOWATT COMBINED ALTERNATING AND DIRECT-CURRENT MACHINE

The 2-kilowatt machine shown in the accompanying drawings is similar in design, construction, and operation to the four-pole machine described in the preceding chapter. The present machine is somewhat larger, runs at a slower speed, and has about double the output capacity of the four-pole machine. Fig. 196 gives an end view of the field-magnet frame. There are six poles of laminated iron cast into a circular yoke of cast iron, which, in turn, is bolted to the base plate by four hexagon cap screws. After the poles are cast in and it is seen that all of them are tight and firm in the yoke, they may be bored out to the proper diameter, 4.04 ins. The armature is to be finished 4 ins. in diameter, so that the air-gap will be .02 in. across at each pole; this will be ample for clearance if care is taken in lining up the machine.

Fig. 197 is a section of the assembled machine which shows the construction and relation of the various parts. The armature is of the usual laminated construction, the core discs being held between two cast-iron flanges screwed upon the shaft. If the armature slots are milled out, the discs must be taken apart, cleaned up, and insulated before being finally assembled on the shaft. If this is not done the eddy current loss will be excessive, causing heating and seriously reducing the available output. Fig. 198 shows a detail of the armature shaft. This is intended to be made from 1-in. cold-rolled steel. Threads are cut at both ends of the core portion to receive the cast-iron flanges which clamp the core punchings. Two keys are provided, as shown in the drawing.

The bearings are made with a brass sleeve fitting the shaft, supported at its center by a projecting web cast in the bracket. Although it is preferable to bore the bracket for this sleeve, the machine work may be avoided by coring the bracket somewhat larger and then babbitting the sleeve into its support when the parts have been lined up in their proper position. The oil rings are of brass $\frac{1}{8}$ in. wide and $1\frac{1}{8}$ ins. inside diameter; grooves

are cut eccentrically in the sleeves to receive the rings, the grooves being made about 5-32 in. wide in order to allow the ring a small amount of play.

The commutator is built up on a machine steel sleeve, with the flanges undercut at 60 degrees. The segments may be cast separately or cast as a solid cylinder and afterward cut into segments on a milling machine. The segments should be of copper, with 1-32-in. mica between them,

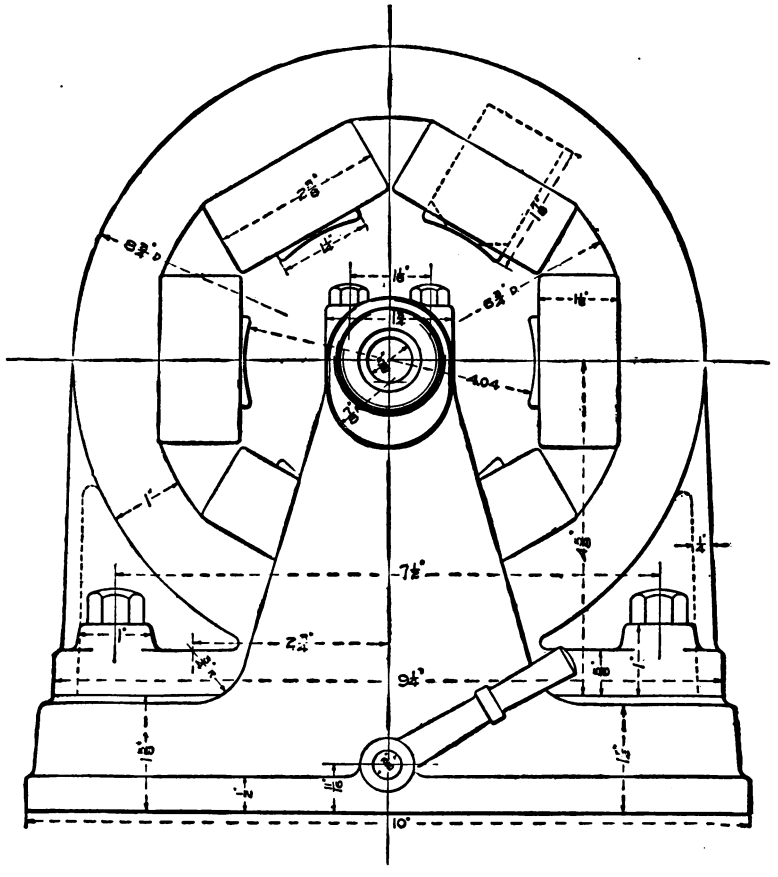


FIG. 196

and 1-16-in. micanite, or equivalent insulation, between the sleeve and segments. The number of segments is 36. The collector rings are six in number and mounted upon a sleeve with 3-32-in. fiber discs between the rings. Connections are made by drilling in from the back and soldering in short leads of No. 8 or No. 10 wire, one to each ring. Each of the leads must be carefully insulated from all rings, except the particular one

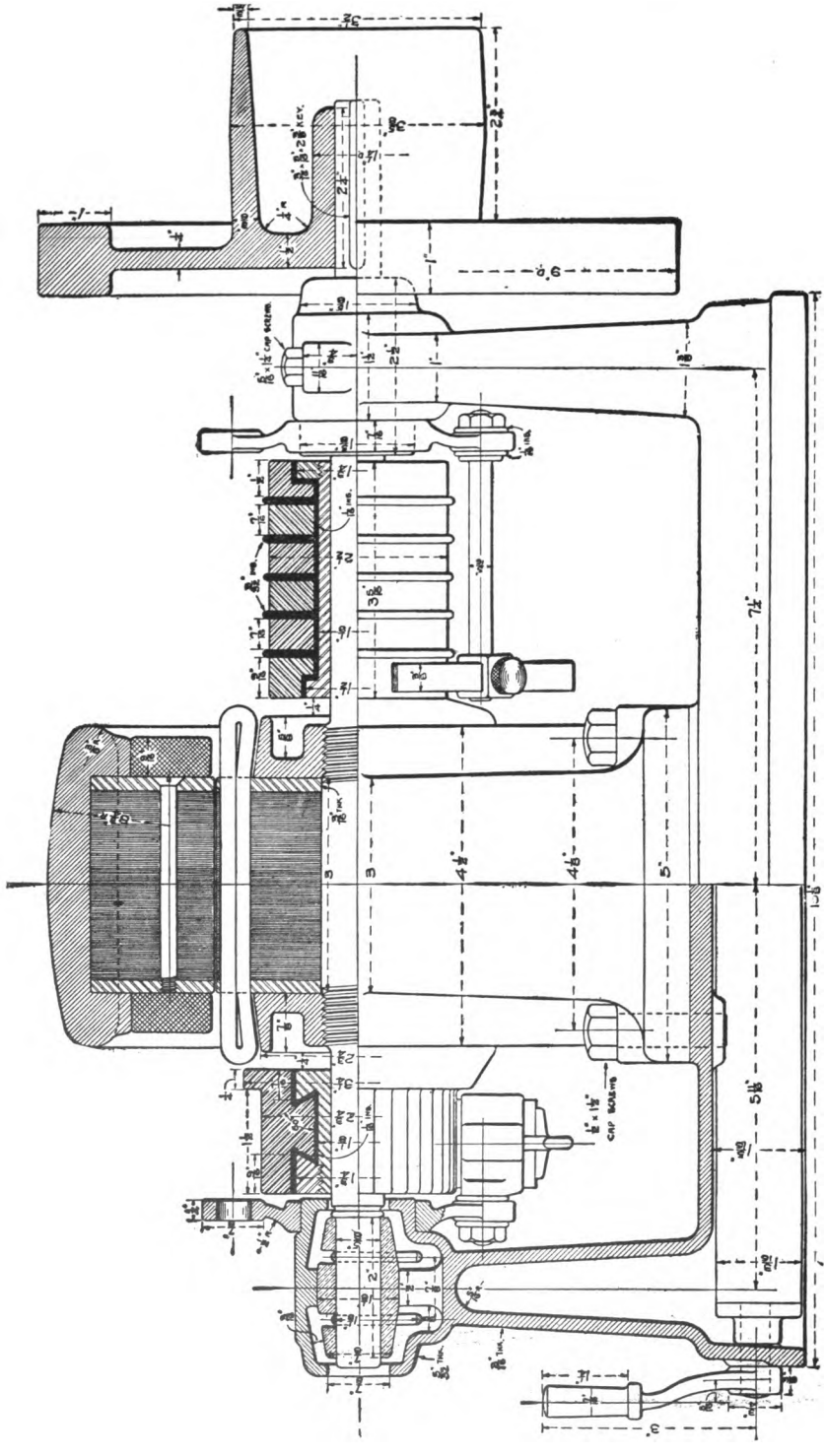


FIG. 197

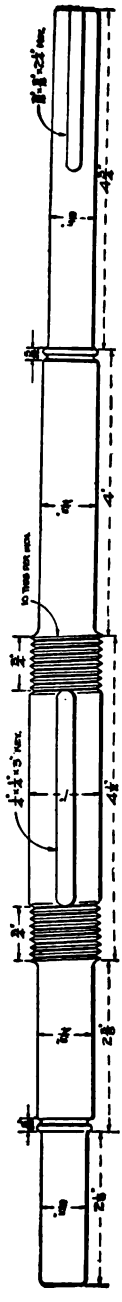


FIG. 198

to which it is electrically connected. Some thin copper strips are to be provided with a wrapping of tape and laid in the bottom of the armature slots, six of which must be made 1-16 in. deeper than the rest to accommodate the strips. These strips carry the current across the armature and are connected to the commutator at the proper intervals.

At the alternating-current end of the machine the fly-wheel pulley is shown in position on the shaft. This style of pulley will be found advantageous in operating the machine as a rotary converter or in driving it by means of a gas engine. If the machine be used as a motor an ordinary pulley will answer. The pulley is for a $2\frac{1}{2}$-in. belt, and is $3\frac{1}{2}$ ins. in diameter.

Fig. 199 shows the brush-holder collar. This answers for both the alternating-current and the direct-current ends of the machine, as there are six collector rings and also six brush-holders. Care should be taken in drilling the holes for brush-holders to have them equidistant, for

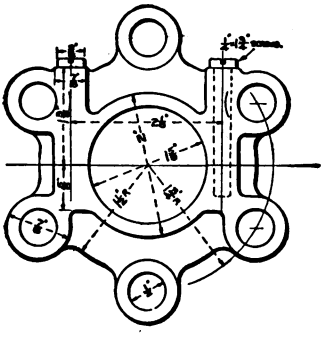


FIG. 199

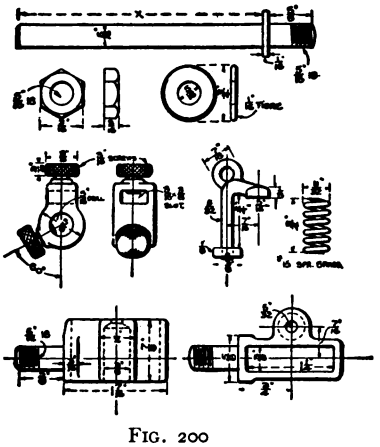


FIG. 200

upon this the accuracy in spacing the brushes around the commutator depends. At the alternating-current end this does not matter particularly. The brush-holder collars are necessarily made in halves, as it would be difficult to assemble the machine with a one-piece collar.

Fig. 200 shows details of the brush-holders. These are of the same type as those already described in connection with the four-pole machine. The alternating-current brush-holders have no spring tension and are designed for leaf-copper brushes $\frac{1}{8}$ in. thick and $\frac{3}{8}$ in. wide. The studs are of different lengths to suit the position of the rings; the dimension, X, is $3\frac{3}{8}$ ins., $2\frac{7}{8}$ ins., $2\frac{1}{4}$ ins., $1\frac{3}{4}$ ins., 1 3-16 ins., and 11-16 in. for the six studs. They are made of 5-16-in. brass rod. The direct-current brush-

holders are designed for radial carbon brushes $\frac{3}{8}$ in. thick, $1\frac{1}{4}$ ins. wide, and $1\frac{1}{8}$ ins. long.

Fig. 201 is an end view of the armature core. There are 36 slots, each 3-16 in. wide and 7-16 in. deep; every sixth slot is made $\frac{1}{2}$ in. deep to allow space for the connection strips referred to above. After the coils are in place the armature must be banded at three points, one band to go around the center of the core, and one around each end of the winding where it projects beyond the core. A groove must be turned in the periphery of the core to accommodate the central band, so that the thickness of the band will not be added to the length of the air-gap. This groove may be turned on the core before the slots are milled out, or it may be done afterward by filling in the slots temporarily with hard wood strips. It should be about 1-16 in. deep and $\frac{3}{8}$ or 7-16 in. wide.

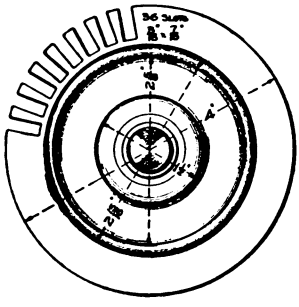


FIG. 201

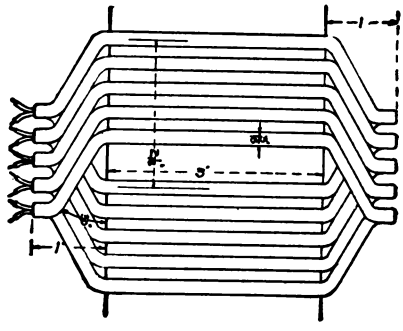


FIG. 202

Fig. 202 shows a development of the armature winding. This is of the "straight-out" type, and is composed of 36 form-wound coils of No. 20 wire, 16 turns per coil. One side of a coil occupies the top half of slot No. 1, and the other side of the same coil occupies the bottom of slot No. 7; that is to say, each coil spans one sixth of the circumference of the core. The terminals are brought out at the apex of the coil, and each is connected to the nearest commutator segment; the inside terminal of one coil and the outside terminal of the adjacent coil connect to the same segment. The point of commutation will be found at or near the center line of the pole-pieces.

Fig. 203 is a diagram of the connections for the collector rings. This arrangement is for a six-pole field. The leads numbered 1 to 6 pass across the armature and are connected to the six collector rings at the alternating-current end of the machine. Connected in this way, single-phase current may be obtained from rings 1 and 2 or 3 and 4, two-phase currents from rings 1 and 2 and 3 and 4, and three-phase currents from rings 1, 5, and 6.

The output and voltage with each of these various methods of working are as follows: Direct current, 15 amperes at 115 volts; single-phase alternating, 15 amperes at 80 volts; two-phase alternating, 11 amperes per phase at 80 volts; three-phase alternating, 9 amperes per phase at 70 volts.

Fig. 204 shows the outline of one of the field coils. These are wound on a form, and each coil is divided into two sections of approximately equal resistance, with separate terminals brought out from each section. The size of wire is No. 23, B. &. S. gage.

The arrangement employed for starting the machine as a motor on single-phase circuits is as shown in the description of the four-pole machine (see Figs. 193 and 195, and the description on pages 157 and 158, with the single exception that in the present machine there are six coils of two sections each instead of four coils of three sections each.

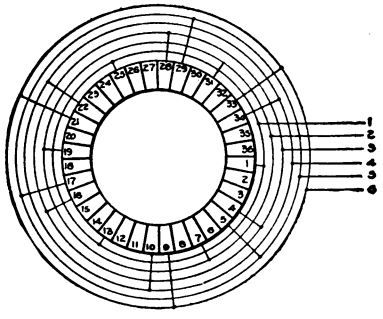


FIG. 203

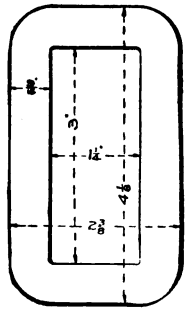


FIG. 204

To operate the machine at 110 volts, direct-current, or 125 cycles alternating, the speed should be 2500 r.p.m. For 60 cycles the only method available is to reduce the speed to 1200 r.p.m. and to connect the field winding in series multiple. This is most conveniently done at the starting switch by changing the wiring of the last row of contacts on the switch cylinder, so that when the switch is in the running position the two sections of each field coil will be in multiple and the six multipled pairs in series and connected across the direct-current brushes. This will reduce the voltage to about one half of its value at the higher speed, and the output will then be as follows: Direct-current, 15 amperes at 55 volts; single-phase, 15 amperes at 40 volts; two-phase, 11 amperes at 40 volts; three-phase, 9 amperes at 35 volts. It is probable that by adjusting the field excitation, the voltage could be brought up to 45 or 47 volts, and thus admit of working directly on single-phase circuits of 50 or 52 volts as a motor or rotary without the use of an individual transformer. For other voltages a transformer will be necessary.

The following is a summary of the data for winding and general dimensions: Speed, 2500 r.p.m. on 125 cycles, or 1200 r.p.m. on 60 cycles. Cast-iron yoke, laminated-iron poles cast in. Armature, 4 ins. in diameter, 3 ins. long; 36 slots 3-16 in. wide, 7-16 in. deep, every sixth slot ½ in. deep; 36 coils of No. 20 wire, 16 turns per coil, 4 wires wide and 4 deep. Total, 1152 conductors. At 15 amperes direct-current output the cross-section of armature conductors is 400 circ. mils per ampere.

Useful lines per pole, at 115 volts and 2500 r.p.m.:

$$\frac{1152 \times 41.6}{115 \times 10^8} = 240{,}000.$$

TOTAL LINES PER POLE, 320,000

Part	Total lines	Cross sect. sq. in.	B.	H.	Length	Ampere turns
Armature	120,000	3.	40,000	10	1.5″	15
2 air-gaps	240,000	4.	60,000	18,800	.04	750
5 teeth	240,000	2.	120,000	180	.44	79
1 yoke	160,000	3.5	46,000	102	3.	106
2 cores	320,000	3.75	85,000	18	2.5	45

Total ampere turns in field winding, 995. Circ. mils field wire (No. 23) $= \frac{11 \times 12 \times 500}{16 \times 12} = 345$. Mean length per turn, 12 inches. Turns (approx.) per coil, 500; 16 layers of 32 turns each. Resis. of field winding (coils in series), 63 ohms. Normal shunt current, 1 ampere (nearly). Use rheostat of about 40 ohms total in field circuit.

Mean length of wire per armature coil, 16 feet. Total length of armature wire, $36 \times 16 = 610$ feet. Total weight of armature wire, 2 pounds. Resistance of armature, 0.17 ohm. Drop in armature winding at full load, 2½ volts.

CHAPTER XXI

FOUR-KILOWATT COMBINED ALTERNATING AND DIRECT-CURRENT MACHINE

THE machine here illustrated is the largest of the machines of the same general type of which this is the third to be described in this book. The present machine has 8 poles; its speed is from 1800 to 1875 r.p.m., and it has an output capacity of four kilowatts.

Fig. 205 shows an end view of the field, base, and bearing pedestals. The field has a circular yoke of cast iron with pole-pieces of laminated wrought iron cast in. About No. 20 gage iron may be used in the poles and they are bored out to 5 9-16 ins. diameter after being cast in. Fig. 206 is a section of the assembled machine, which shows the construction and relation of the various parts. The armature core is built up of soft iron discs about No. 27 gage, having an external diameter of $5\frac{1}{2}$ ins., with a $2\frac{1}{2}$-in. hole in the center. The discs are mounted upon three-arm spiders, one at either end of the core, and the arms of which intermesh about $\frac{1}{2}$ in. at the center of the core, so that all the discs are supported at least three points, and at the same time the air has free access to the interior of the core. Distance pieces are provided at two points in the core which divide the laminations into three groups with 3-16-in. ventilating ducts between them. Two hexagonal nuts upon the shaft provide means for clamping the core discs and spiders.

The commutator, which is shown partly in section, is $3\frac{1}{2}$ ins. in diameter and $1\frac{3}{4}$ ins. wide on the face. There are 48 segments of copper with $3\frac{1}{2}$-in. mica between them, and 3-32-in. insulation separates the segments from their supporting sleeve. The sleeve is of machine steel and has flanges undercut at an angle of 60 degrees. The collector rings are six in number and are made of copper. The rings at the ends are $\frac{5}{8}$-in. wide; the rest are $\frac{1}{2}$ in.; $\frac{1}{8}$-in. insulation separates the rings from each other. The bearings have a brass sleeve fitting the shaft, and this is slotted to allow oil rings 5-32 in. wide to revolve freely with the shaft.

Fig. 207 is a detail of the armature shaft. This is designed to be made

from a piece of $1\frac{1}{4}$-in. cold-rolled steel. Threads are cut at both ends of the core portion to receive the hexagonal nuts which compress the core discs.

At the alternating-current end of the machine the fly-wheel pulley is shown in position upon the shaft. A pulley of this kind will be found very useful in operating the machine as a rotary or in connection with a gas engine for driving, as it assists the armature in maintaining a uniform rate of rotation.

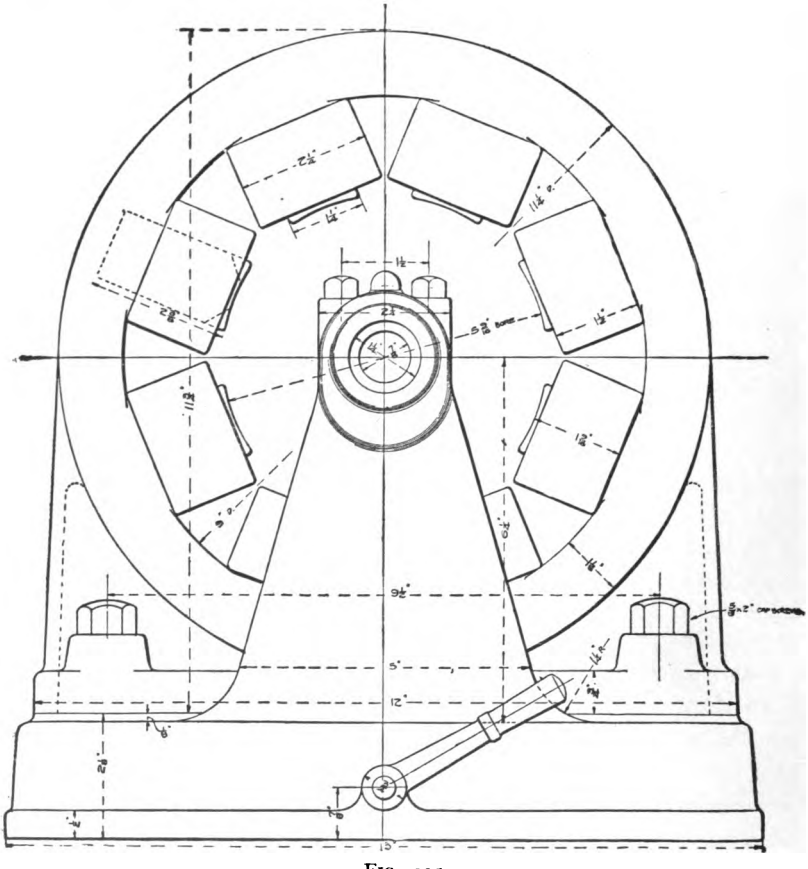


FIG. 205

Figs. 208 and 209 show the brush-holder collars or so-called "quadrants" for the alternating-current and direct-current ends of the machine. The one at the direct-current end has eight lugs for supporting the eight brush-holders, and the alternating-current end has six, one for each of the six rings. Both are made in halves and screwed together after being placed in position on the bearings.

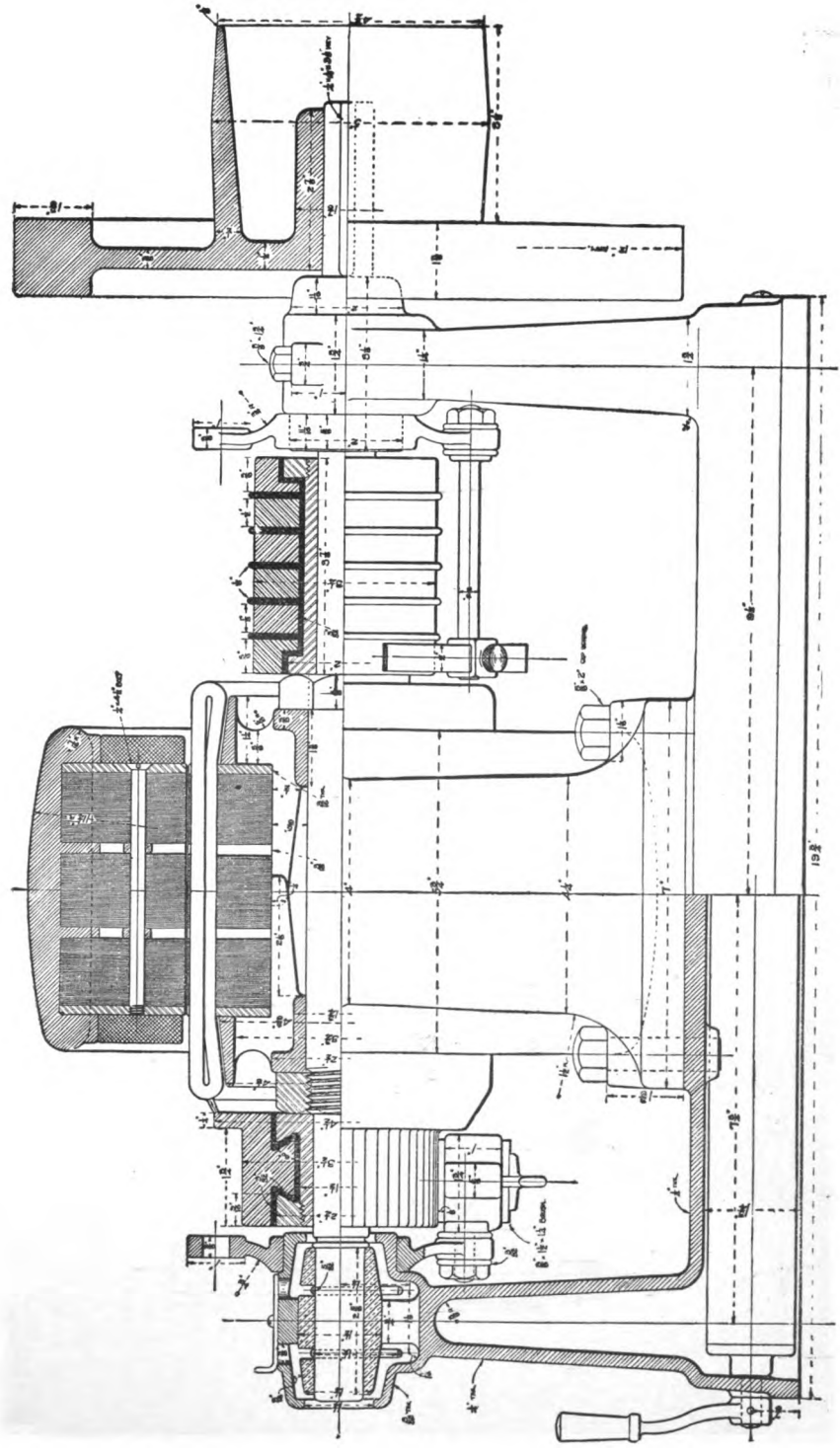


FIG. 206

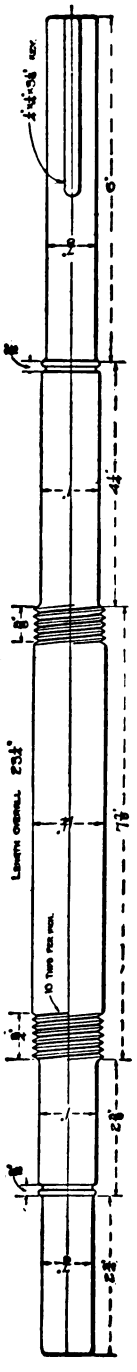
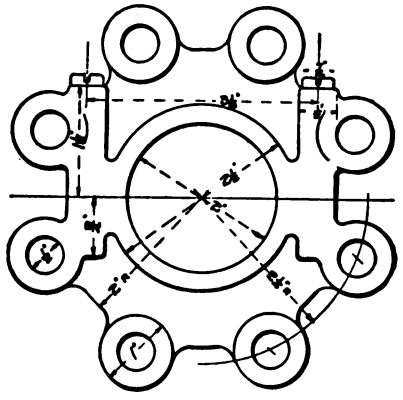
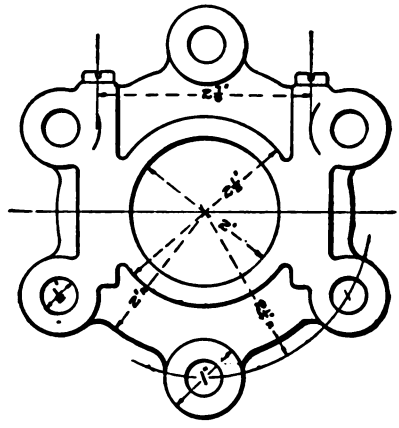


FIG. 207





FIGS. 208 AND 209

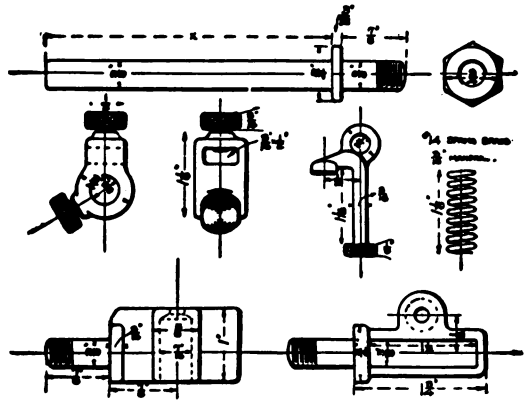


FIG. 210

Fig. 210 shows details of the direct-current and alternating-current brush-holders. The direct-current holders are for radial brushes, $\frac{3}{8}$ in. thick, $1\frac{1}{2}$ ins. wide, and $1\frac{1}{4}$ ins. long, and are provided with a spring tension arrangement, the details of which are shown in the engraving. The alternating-current brush-holders are for copper-leaf brushes $\frac{1}{8}$ in. thick and $\frac{1}{2}$ in. wide; the spring of the brush itself will be found sufficient to give proper contact with the collector rings. The studs which support these holders are of different lengths to suit the position of the various collector rings. The dimension marked x on the drawings has the values $3\frac{7}{8}$ ins., $3\frac{1}{4}$ ins., $2\frac{5}{8}$ ins., 2 ins., $1\frac{3}{8}$ ins., and $\frac{3}{4}$ in. for the six studs respectively. They are best made of $\frac{3}{8}$-in. brass rod.

Fig. 211 shows an end view of the armature core. There are 48 slots, 3-16 in. wide and $\frac{1}{2}$ in. deep. If these slots are milled out, it will be necessary to take the discs apart after this operation in order to anneal and insulate them before the final assembling. Annealing will improve the discs, which will have become somewhat hardened from the machine work which has been done upon them.

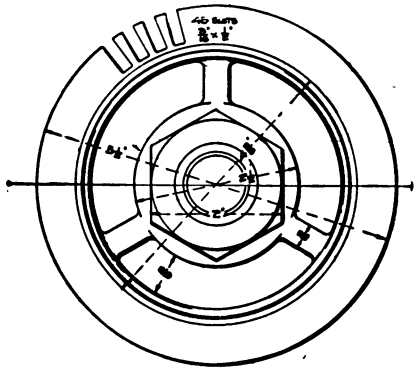
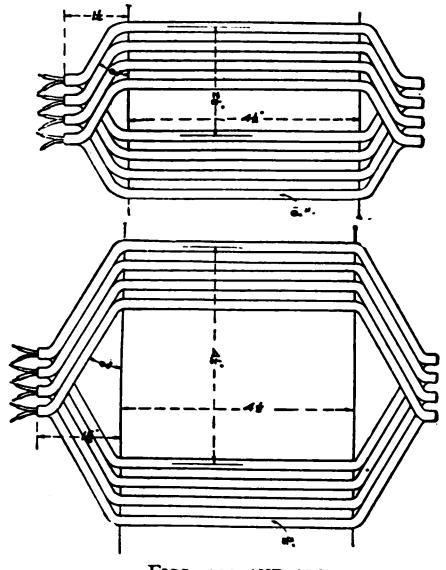


FIG. 211



FIGS. 212 AND 213

Figs. 212 and 213 show developments of the armature winding. This is of the "straight-out" type and is of two forms, known as the "short coil" (Fig. 127), and "long coil" (Fig. 128). The long coil is for use in a four-pole field and for 60-cycle work. The short coil is for eight poles and 125 cycles. These coils are form wound of No. 17 double-cotton-covered wire, 12 turns per coil. The terminals of each coil are brought out at its apex, and are connected to the two nearest commutator segments, inside terminal of one coil and the outside terminal of the adjacent coil

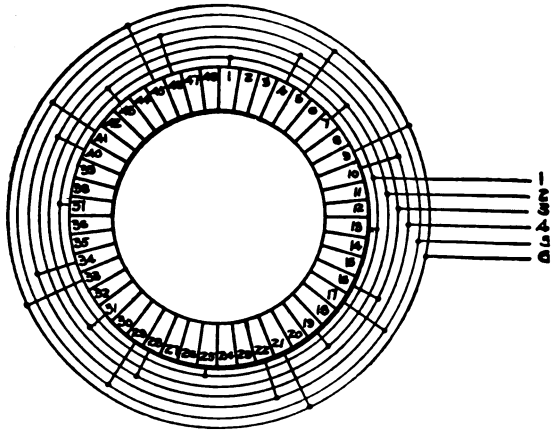


FIG. 214

connecting to the same segment. This will bring the neutral point or line of commutation at or near the center of the pole-pieces.

Figs. 214 and 215 are diagrams to guide in making taps to the collector rings. The eight-pole arrangement is intended for operating on 125-cycle circuits, and the four-pole for 60-cycle circuit. The necessary

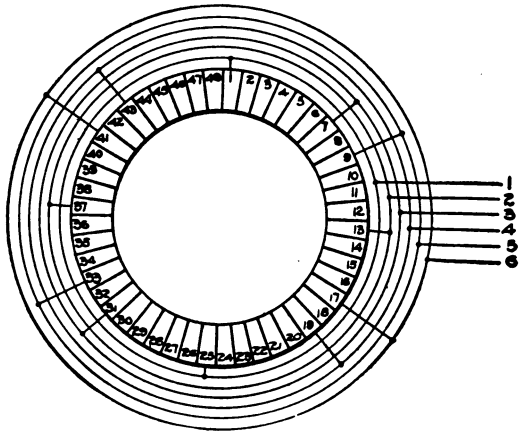


FIG. 215

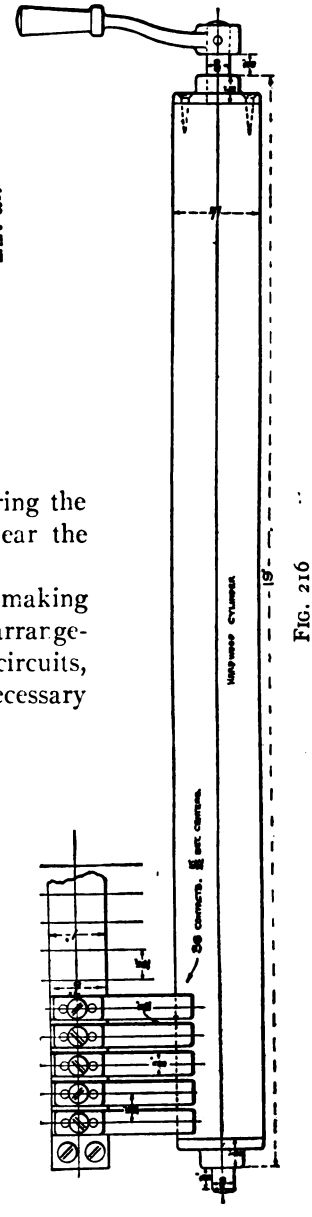


FIG. 216

interconnections between segments may be made at the back of the commutator before it is placed in position on the shaft. For instance, in the eight-pole arrangement, segments 1, 13, 25, and 37 are connected together

and to a lead marked No. 1. The leads numbered 1 to 6 inclusive pass through the air space in the center of the core and connect to the corresponding rings. Thus connected, single-phase current may be obtained from rings 1–2 or 3–4; two-phase currents from 1–2 and 3–4, and three-phase currents from 1–5–6. The outputs and voltages are as follows:

	Amperes	Voltage
Direct-current	35	115
Single-phase alternating..	35	80
Two-phase alternating...	25 per phase	80
Three-phase alternating..	21 per phase	70

Figs. 216 and 217 show the details of the

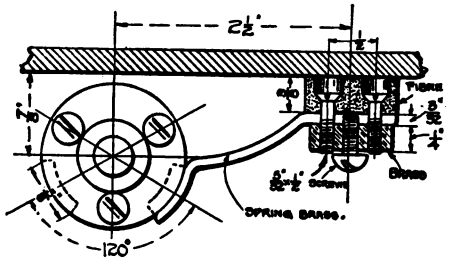


FIG. 217

switch cylinder and contacts which are located in the base of the machine and serve as a starting device for operating on single-phase circuits.

A strip of fiber 19 ins. long, 1 in. wide, and ⅜ in. thick is fastened to the under side of the cast-iron base and upon this are mounted 38 contact springs, each ⅜ in. wide. The cylinder is of hard wood 1½ ins. in diameter, and is of the proper length to just go inside the base and have its ends journaled therein. The free ends of the contact springs press upon the cylinder and make connections with the contacts fastened upon the cylinder, but they can only be in connection with one row at a time. Fig. 217 is an end view showing details.

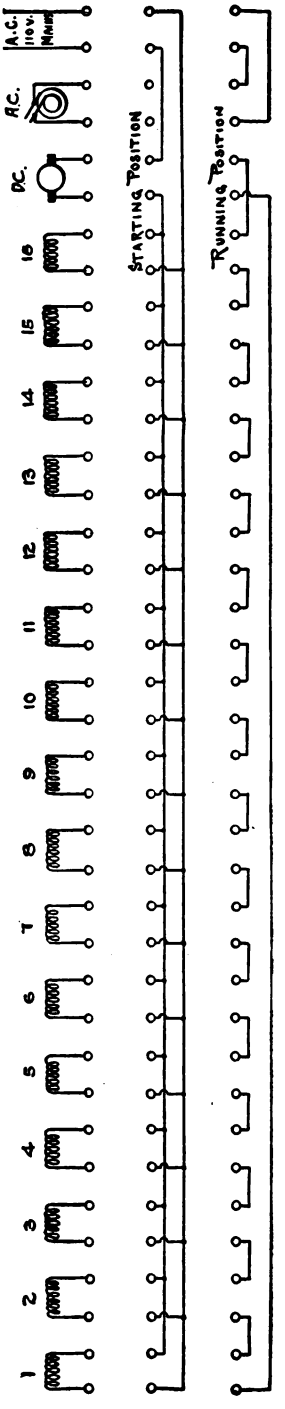


FIG. 218

The diagram, Fig. 218, shows how the connections are made to the switch contacts. The uppermost row of small circles indicates the contact springs to which the sectional field winding is connected. There are eight coils of two sections each, making 16 pairs of terminals to be connected to the switch. The remaining three pairs of contacts connect with the direct-current brush leads, alternating-current rings, and single-phase mains in the manner indicated. The lower two rows of circles represent the contact pieces upon the revolving switch cylinder, these being simply connected in groups by means of short wires or metal strips fastened upon the cylinder itself and occupying that position of the cylinder over which the contact springs are not required to pass.

The action of this device may readily be followed by assuming that the "starting" row of contacts has been moved up to engage the contact springs, when it will be seen that all the field sections are in multiple, the armature in series with them, and the whole placed across the single-phase alternating-current mains, so that the machine starts as a series motor. When the second row of contacts engages the contact springs the field sections will be in series and placed in shunt across the direct-current brushes, while at the same time the single-phase supply current is connected to the collector rings, and the machine is now operating as a synchronous motor, exciting its field from the direct-current end, which is the normal running condition.

To operate the machine at 110 volts direct current or 125-cycle alternating current no changes are necessary and the speed will be 1875 r.p.m. For 60-cycle alternating-current work the number of poles is halved by reversing the terminals of any two successive field coils, skipping the two coils and reversing the next two; this being most conveniently done by changing the connections at the starting switch. This change, together with the "long coil" winding and the diagram of connections for four poles, fits the machine for operating at 60 cycles. The speed will now be 1800 r.p.m. and the voltage and output practically the same as before.

The following is a brief summary of the general dimensions and data for winding:

Eight-pole machine: 1800 r.p.m. at 60 cycles; 1875 r.p.m. at 125 cycles. Armature $5\frac{1}{2}$ ins. diameter, 4 ins. long, 48 slots 3-16 in. $\times$ $\frac{1}{2}$ in.; 3-16 in. = 188 in. width of slot, allowing three No. 17 wires and insulation of 18 mils; 5 in. depth slot, taking eight No. 17 wires and insulation and bands of 45 mils., giving 24 conductors per slot. Total, 1,152 conductors. Direct-current output at 470 circ. mils per ampere = 36 amps.

There will be 455 ampere-turns in each field coil. Mean length of 1 turn = 13.5 inches circ. mils shunt wire $= \frac{11 \times 13.5 \times 455}{12 \times 12} = 465.$

Use No. 23, having 509 circ. mils, .034 in. diam., d.c.c.; 620 turns (approx.) per coil, in 14 layers, 44 turns wide. Wind in two sections and bring out individual terminals from each section.

Resistance of shunt field $= \frac{8 \times 620 \times 13.5 \times 20.3}{1000 \times 12} = 114$ ohms.

Normal shunt current $= \frac{450}{620} = .75$ amp. Use rheostat of about 40 ohms in shunt field. Weight of wire in shunt coils:

$$\frac{8 \times 620 \times 13.5 \times 1.54}{1000 \times 12} = 8.5 \text{ lbs.}$$

Total length of wire on armature:

$$\frac{48 \times 18 \times 12}{12} = 864 \text{ feet.}$$

Total weight of wire on armature:

$$\frac{864 \times 6.2}{1000} = 5.37 \text{ lbs.}$$

Resistance of armature:

$$\frac{1000 \times 64}{864 \times 5.04} = .068 \text{ ohms.}$$

Drop in armature at full load:

$$36 \times .068 = 2.45 \text{ volts.}$$

Part	Material	Total lines	Cross-section	B.	H.	L.	Ampere turns
1 armature	Wrought iron	170,000	4. in.	42,500	4	1.5	6
2 air-gaps	Air	340,000	6.	56,600	17,880	.0313	566
5 teeth	Wrought iron	340,000	3.	113,000	108	.5	54
2 cores	Wrought iron	420,000	5.	85,000	18	1.7	31
1 yoke	Cast iron	210,000	4.7	42,000	68	3.7	252
Total ampere-turns							909

CHAPTER XXII

SINGLE-PHASE RECTIFIER

THE accompanying drawings and description constitute a design for a machine to "rectify" single-phase alternating current; that is, to change it into a pulsating direct-current without changing its e.m.f.

Fig. 219 shows an end view of the field-magnet with two coils in

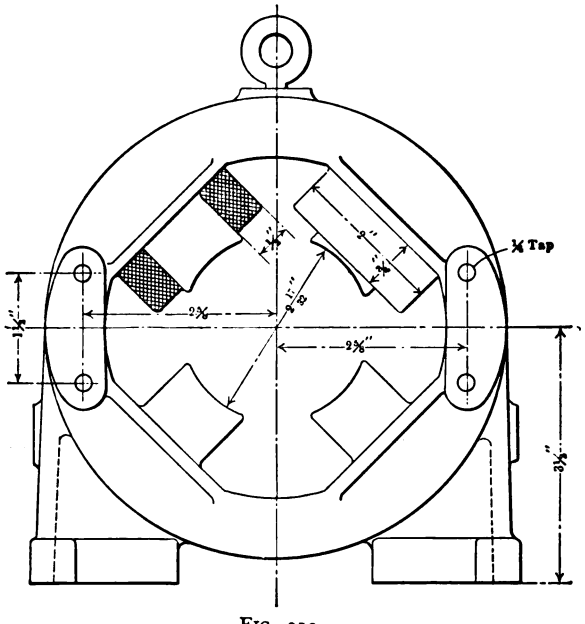


FIG. 219.

place. The circular yoke, magnet poles and feet are cast in one piece, thus avoiding joints in the magnetic circuit and reducing the machine work to a minimum. The pattern for the field casting should be made in two pieces, the parting being made along the line *A–B* in Fig. 220.

Fig. 221 shows the details of the journal-box bracket, journal-box and oil ring. The bracket is bolted to machined seats on the field-magnet yoke (see Fig. 219). The difficulty in securing proper alignment with this construction is less than that of handling and machining the field magnet when journal bracket arms are cast integral with it.

Fig. 222 shows a section through the armature, commutator, and collector rings. The armature core is built up of laminated iron in the usual way, and held together by heavy washers of wrought iron threaded on the shaft at either end. A cast-iron core may be used, though it will, of course, heat up more than the laminated one.

The commutator and collector rings are preferably made of copper,

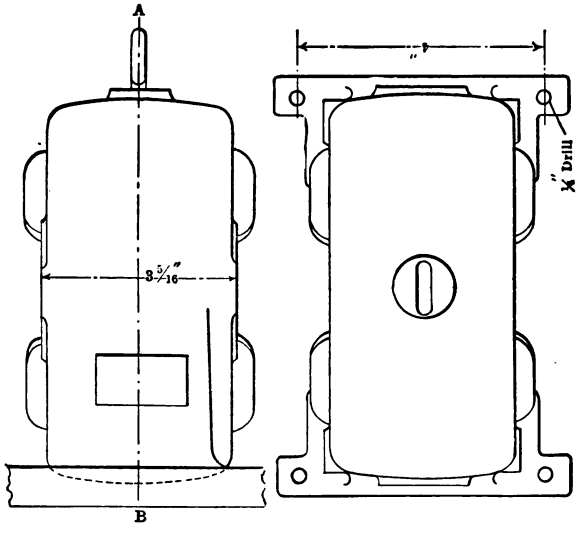


FIG. 220.

through brass may be used. A piece of ingot copper can be obtained and forged into a circular blank suitable for turning up into rings and a commutator. The commutator is turned as a solid cylinder of the required section, and it is then cut into four equal segments with a milling machine, or with a sharp hacksaw and hand power, if a milling machine is not available. The segments are then built up with mica insulation and clamped in a brass sleeve fitting the shaft.

It is well to follow the design of arc machine commutators to some extent and to allow about 1-16-in. air insulation between the segments at the top. Thus the mica insulation will not be injured if sparking occurs. Oil and copper dust should not be allowed to accumulate in the air spaces thus formed, as this would cause a severe short-circuit.

Connections are made between the collector rings and commutator bars with some strips of copper about 1-32 in. thick and $\frac{3}{8}$ in. wide, laid in the armature slots, which have been made about 1-16 in. wider than would otherwise be necessary in order to accommodate both the coils

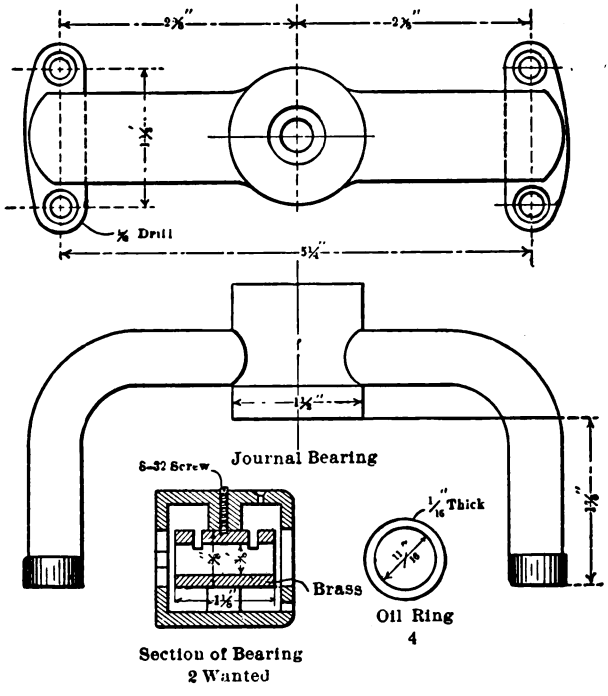


FIG. 221.

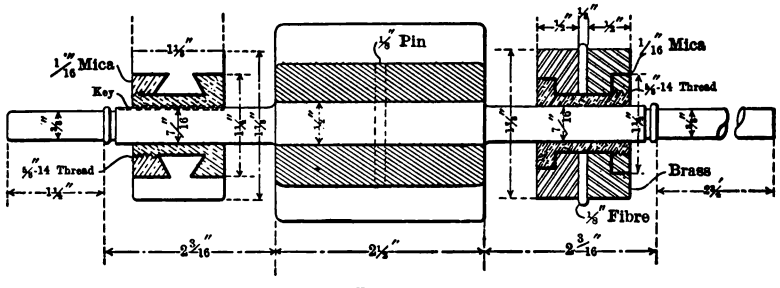
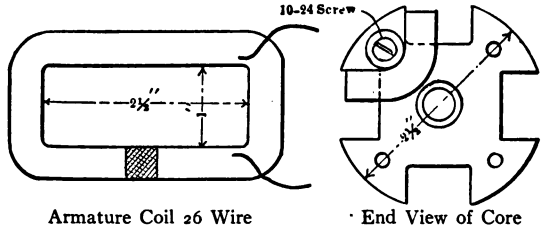


FIG. 222.

and the connection strips. The back collector ring is drilled with $\frac{1}{8}$ in. holes at four equidistant points; two of these holes, the opposite ones, go through the ring and part way into the front ring, the other two holes are

drilled only part way in. Some short pieces of copper wire, about No. 10, are soldered one into each hole, the two wires from the front ring being insulated from the other ring where they pass through it. The four wires are soldered one to each strip, and these carry the current across the armature and connect to the commutator segments.

Diametrically opposite segments of the commutator are thus connected to the same collector ring, and neighboring segments have between them the whole potential difference of the alternating circuit. It is much better not to connect the copper strips permanently to the commutator until the builder has decided where he wishes to place the brushes; the commutator may then be twisted around on the shaft to the correct position and the connections made permanently. The brushes may be placed wherever they will be most convenient, the only restriction being that they must be 90 degrees apart and must pass from one segment to the next at the same instant that an armature tooth is exactly under a pole.



Armature Coil 26 Wire
For 110 Volts
4 Wanted

End View of Core

FIG. 223.

Fig. 223 shows an armature coil and the method of placing the coils upon the core. The coils are wound on a form, and, after being taped, are slipped over the top of a tooth. The slack is then taken up by bending the ends down in a semicircular shape and fastening them in this position by screws which carry small fiber or hard wood bushings.

In addition to this the armature should be banded at one or two points with No. 28 brass or German silver wire, small notches having been turned in the core to receive the bands and allow them to come flush with the surface of the core.

With an iron-clad armature like this, the clearance need not be more than from 1-64 in. to 1-32 in.; just how much it will be depends somewhat on the builder's skill; 1-64 in. clearance has been indicated on the drawings, and with care taken in adjustment it should not be difficult to obtain this figure. Fig. 224 shows end views and a cross-section of the rectifying commutator. Fig. 225 is a fly-wheel pulley which it will be found advisable to use in order to obtain smooth running.

Fig. 226 shows the brush-holder yoke and brush-holders. The bearings, while not so simple in construction as some other designs, have proven very satisfactory. The rings carry up a plentiful supply of oil, and what runs out at the end returns to the well and does not fly off outside the bearing and spatter the surroundings.

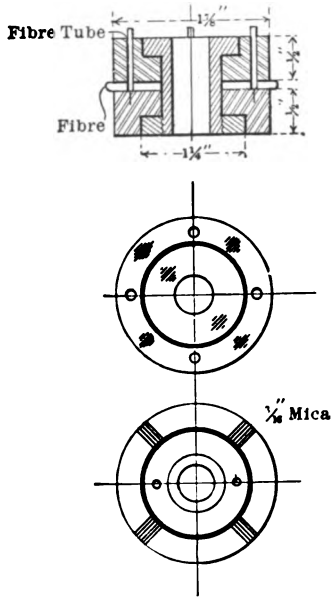


FIG. 224.

In finishing the bearings the bracket arms are preferably faced up first. The bracket is then bolted to a face-plate and the box is bored out to a diameter of $\frac{5}{8}$ in. clear through. Then the outside of the inner boss is turned off $1\frac{1}{2}$ ins. diameter where it is to receive the brush yoke. The sleeve which forms the bearing proper is turned a tight fit for the bore of the box, so that with but little pressure from the centering screw it is held firmly in place. The grooves for oil rings can be cut in the sleeve conveniently by mounting it eccentrically in the chuck and using a thin cut-off tool.

The brush yoke is shown with two arms 90 degrees apart. Another pair of arms and brushes might be added if it is desired to have more current-carrying capacity.

The direct-current brushes had better be larger than the alternating-current brushes, and the holders should have spring tension, unless a very springy brush is used. Copper brushes are better for this purpose than carbon, as they make better contact and cause less sparking.

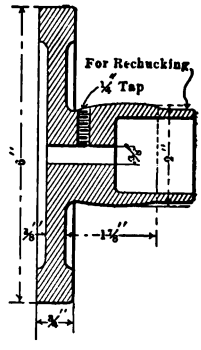


FIG. 225.

Figs. 227 and 228 show the field and armature coils respectively, with the forms upon which they are wound. The former is best made of hard wood, and consists of a block and two flanges, all held together by two wood screws and having a $\frac{1}{2}$-in. hole through the center for placing on a mandrel in the lathe. The block should be made a trifle larger than the pole over which the finished coil is intended to go, and it should be given a slight taper of about 1-16 in., so that it can be readily slipped out of the finished coil.

Before beginning the winding a short piece of tape is laid in the long

sides of the former, with the ends left sticking out. When the form is wound full these pieces of tape are tied tightly over the coil, and will hold it in shape while the former is taken apart and the coil is receiving its

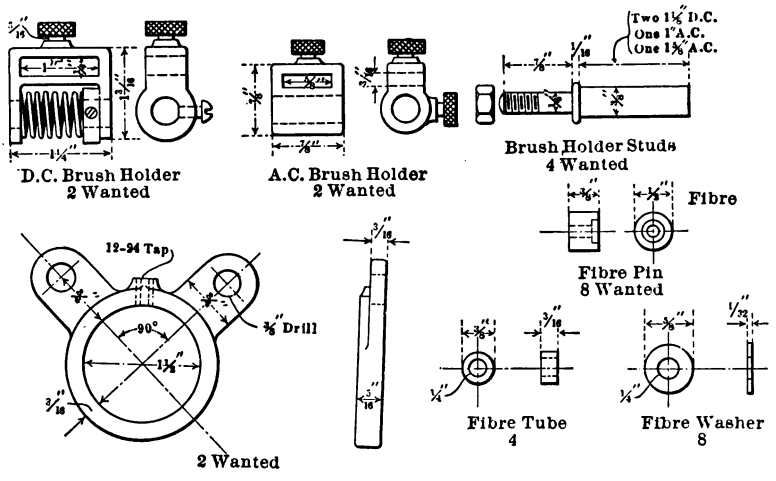
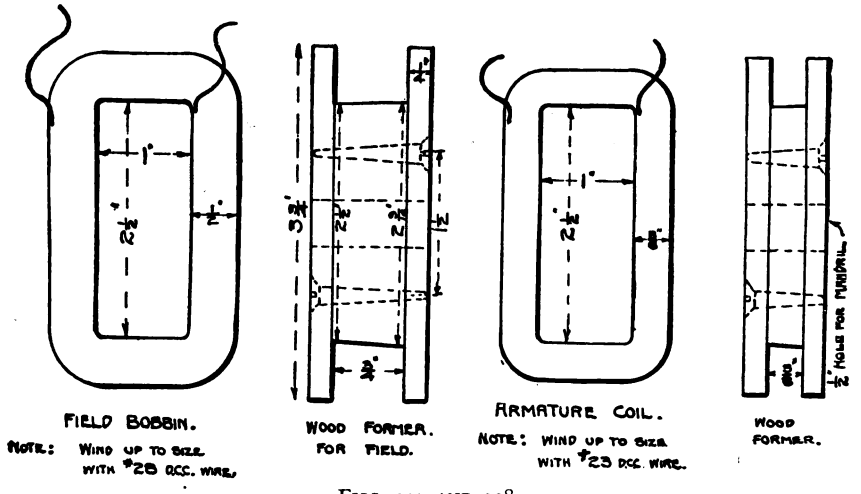


FIG. 226.

wrapping of tape. After being shellacked and dried, the coil is placed on the poles and hard wood wedges driven in between coil and pole, thus holding it securely in place.


FIELD BOBBIN.
NOTE: WIND UP TO SIZE WITH #28 D.C.C. WIRE.
WOOD FORMER FOR FIELD.
ARMATURE COIL.
NOTE: WIND UP TO SIZE WITH #23 D.C.C. WIRE.
WOOD FORMER.

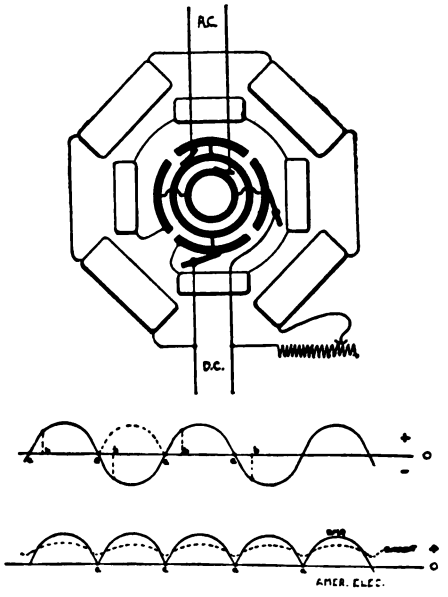
FIGS. 227 AND 228.

The same form may be made to serve for both field and armature coils, if the field coils are wound first, and then the block reduced in thick-

ness from $\frac{3}{4}$ in. to $\frac{3}{8}$ in., the armature coils having the same inside dimensions as the field coils, but being only half as thick.

The fields are wound with No. 28 double-cotton-covered wire and the armature with No. 23. If the coils are wound to the specified dimensions they will have nearly enough the required number of turns.

Fig. 229 shows a diagram of connections and Fig. 230 some e.m.f. curves. For 100 volts the field and armature coils are connected four in series, as shown. For 50 volts the coils may be connected two in series and the twos in multiple. The armature terminals are tapped onto the



FIGS. 229 AND 230.

collector rings, or what amounts to the same thing, placed across any two successive commutator segments.

The connections on both armature and field should be such as to produce alternate north and south polarity all the way round. If all the coils have been wound in the same direction and placed on the poles the same way, connect beginning to beginning and ending to ending, and the polarity will be right. The machine will run at 1800 r.p.m. on a 60-cycle circuit, and on a 125-cycle circuit it will have to make 3750 r.p.m. This it can easily do if the armature is as well balanced as it should be.

Since the strength of the field has a considerable effect on the behavior of a synchronous motor, it is best to have an adjustable resistance in the

field circuit of this machine, so that the field can be adjusted until the minimum armature current is obtained.

Referring now to the curves in Fig. 230, it is clear that if the rectifier is running in synchronism and the angular position of the brushes is correct, the brushes will pass from segment to segment at the instant when the e.m.f. curve reaches its zero value at the points, *a*, *a*, *a*, etc. As the brushes in passing from segment to segment overlap two segments for a brief interval, they form a dead short-circuit on the alternating-current mains during the interval. This will not, however, result in any damage if the e.m.f. becomes zero at the same instance. If, however, the brushes had been incorrectly placed and commutation occurred at the points, *b*, *b*, *b*, etc., an e.m.f. of value equal to the ordinate at *b* would be short-circuited four times in a revolution, and serious sparking would result.

This state of affairs is easily remedied by shifting the brushes, which corresponds to changing the angular position of the point of commutation, until a position such as *a a* is reached, when all sparking will disappear. If the armature falls out of step, or if it is thrown into circuit before complete synchronism is reached, a short-circuit travels over every portion of the e.m.f. wave, at a slow rate equal to the difference between synchronous speed and the actual speed at that instant, the result being a magnificent display of fireworks and probably a blown fuse.

To obviate this latter difficulty a resistance or choking coil should be placed in series with the alternating-current end at the moment of starting, and cut out when it is seen that the machine has settled down to steady running. Such a resistance will not have any appreciable effect on the small current drawn by the armature and field windings, but should be of such a value as to limit the current to about 10 amperes, should a short-circuit occur.

The ordinary method of using a synchronizing lamp is not easily applicable here on account of the small size of the machine; and, moreover, a little practice will enable the operator to judge by ear the proper instant for closing the circuit.

By making slight changes in the connections, as already pointed out, this machine may be used as a rectifier on single-phase circuits of 50 or 100 volts and 60 or 125 cycles. The amount of rectified current which may be drawn is not limited in any way by the horse-power capacity, but will generally be limited only by the capacity of the transformer which is supplying the current and by the current-carrying capacity of the brushes and other parts of the main circuit. Thus from 50 to 100 amperes may be drawn, depending somewhat on the nature of the load into which the rectifier is feeding current.

The machine may also be used as a self-exciting synchronous motor,

developing from 1-10 to ⅛ horse-power, according to the strength of field; and finally it may be driven by belt as a self-exciting alternator, supplying

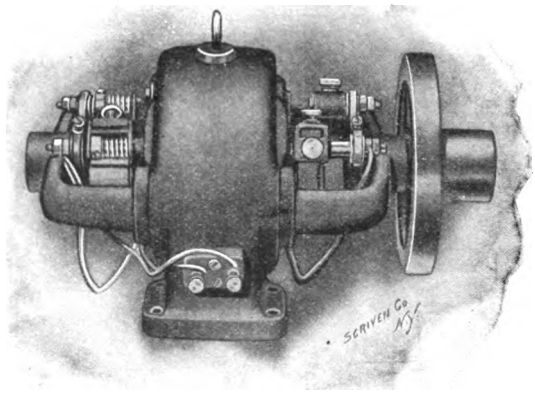


FIG. 231.

either an alternating current or a rectified direct current, or both, up to about 100 watts output.

Fig. 231 was reproduced from a photograph illustrating a rectifier built from this design by Parsell & Weed, New York.